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Discussion of all papers is invited

VOL. 17 MAY, 1927 No. 5

THE INDIANAPOLIS WATER COMPANY RATE CASE[1]

BY JOS J. DANIELS[2]

In October, 1924, Judge Geiger, sitting in the United States District Court for the District of Indiana, at Indianapolis, in a suit brought by the Indianapolis Water Company against the Public Service Commission of Indiana, issued a permanent injunction against the enforcement of certain rates theretofore prescribed by the Commission, on the ground that those rates were not sufficient to yield the Water Company a reasonable return upon the fair value of its property and therefore were confiscatory and in violation of the Water Company's rights under the 14th Amendment to the Federal Constitution. The case was appealed by the defendants to the Supreme Court of the United States and was argued before that court last April. On November 22, 1926, the Supreme Court handed down its opinion, written by Mr. Justice Butler, affirming in all respects the decree of the District Court. I have been asked to comment today on the salient features of that decision.

I think it may fairly be said that the case is, and will be for some time to come, a land-mark in the law relating to the valuation of utility properties for rate-making purposes. It certainly is so regarded by the bar generally and by the utilities. Almost every day, and certainly on an average of once a week, our office receives a

[1] Presented before the Indiana Section meeting, February 18, 1927.

[2] Attorney-at-Law, Indianapolis, Ind.

request for copies of the Water Company's brief or of the printed record in the case. You may be interested to learn that counsel for the railroad companies, many of whose properties are approaching a final valuation by the Interstate Commerce Commission regard the case as having an extremely significant bearing on their present problems.

Much that is inaccurate and misleading has been written and said about the decision. Like any other court decision dealing with complicated details and difficult legal questions, the decision must be carefully studied in order to be correctly understood and explained. I shall not discuss the erroneous statements that I have seen and heard concerning the case, but I shall endeavor to give you, concisely and accurately, the questions of law which the case decides.

The opinion discusses and passes upon seven legal propositions relating to the valuation of utility properties for rate-making purposes. I shall take these up in substantially the order in which the Supreme Court decided them.

I. HOW IS THE PRESENT VALUE OF A UTILITY PROPERTY TO BE ASCERTAINED?

At the outset, it should be kept in mind that in all cases where property, or its use, is to be taken for the benefit of the public, the main question to be settled is: What is the "present value" of the property? No one contends that any value other than the *present value* is to be ascertained and declared. If the property be real estate, and therefore has a market value, the present market value is the present value to be ascertained and declared. If it is a public utility plant made up of many parts, which plant as a whole has no *market* value, the simple rule of market value cannot be applied, and in such cases, the law, by the courts, lays down rules, which the fact-finding tribunal—court or commission—must follow in determining what is the "present value" of the property that must be found and adjudged. In the Indianapolis Water Company case opinion the Supreme Court has, I believe, clarified those rules and made them more explicit than in any of its previous opinions on this subject. It has been said that the opinion holds unqualifiedly that present value is to be ascertained on one basis only, viz., the basis of the cost of reproduction new at present prices, less depreciation, if any; in other words, that so-called "spot reproduction cost" measures, and is the only measure of, present value. The opinion does not so hold. But

it does lay down, more definitely than the court had done in any of the prior rate cases, certain rules and guides to the ascertainment of present value, and these rules, taken together, will, if properly applied in any given case, lead to a correct determination of what the Supreme Court thinks is present value. These rules may be summarized as follows:

Original cost is a fair measure of present value if, *and only if*, there has been no substantial change in the level of wages and prices since the plant was originally constructed. For example, the present value of a plant constructed a year ago may fairly be measured by its actual cost, for there has been no substantial change in price levels in the past year, but, the Supreme Court says, original cost has no pertinency at all in determining present value when there has been a substantial change in the level of wages and prices since the construction of the plant. In ascertaining the value of a plant in 1927, the Supreme Court would reject as irrelevant evidence of its cost in 1907.

Spot reproduction cost, as I have said, is not the *only* measure of present value. It is the measure of present value in the absence of proof of facts requiring some departure therefrom. What are such facts? They are the facts adduced with reference to the probable level of prices and wages during a reasonable period in the immediate future. The opinion states: "In the light of all the circumstances there must be an honest and intelligent forecast as to probable price and wage levels *during a reasonable period in the immediate future.* In every confiscation case, the future, as well as the present, must be regarded." For illustration, suppose that the present spot reproduction cost of a property is $1,000,000; but proof is adduced that the trend of prices is unmistakably downward and will, so far as can reasonably be foreseen, continue so for at least two or three years. The Supreme Court, in such a case, would sustain, as non-confiscatory, a present-value finding of less than $1,000,000. The converse would necessarily be true, if there was clear proof of a definite upward trend in wage and price levels But if there is no proof of a trend either way for a reasonable future period, then present construction cost is the fair measure of present value. The Court says: "If the tendency or trend or prices is not definitely upward or downward, and it does not appear probable that there will be a substantial change of prices, then the present value of lands, plus the present cost of reconstructing the plant, less depreciation, if any, is a fair measure of the value of the physical elements of the property." Thus there

must be in every case more than a mere slapping of the yard-stick of spot reproduction prices to the plant under evaluation. A common-sense and good faith forecast of "probable price and wage levels" for the next few years must be applied to the present reconstruction figures. The result will be present value.

The Supreme Court had—at least many of us thought that it had—laid down substantially the foregoing rules in the Southwestern Bell Telephone Company and the Bluefields Water-Works case, decided in the spring of 1923. But following closely on these last two cases came the Georgia Railway and Power Company case, which many commissions and municipalities and others felt denied the logical implications of the Southwestern Bell and the Bluefields decisions and left the Supreme Court's position still undefined and uncertain on the question of the weight to be given to testimony of present reproduction cost and original cost figures. The Indianapolis Water Company case is the first case since the three above-mentioned to present squarely to the Supreme Court the question of the ascertainment of present value. The decision is therefore especially significant and note-worthy, and I think it will be agreed by every fair-minded person who studies the opinion, whatever his personal leanings and affiliations may be, that the decision lays down the rules which I have briefly stated above, on the subject of the correct method of finding the present value for rate-making purposes of a property devoted to the public service.

May I point out, briefly, before I leave this subject, one fact that I think has been generally over-looked in contemporary discussions of the rule of present value? Although it has been useless for years, in the light of many Supreme Court decisions, to argue for original cost as a measure of present value where there has been a substantial change in price and wage levels, and although it is equally useless, in the light of the Indianapolis Water Company decision and other Supreme Court cases, for the alleged protagonists of the peoples' interests to inveigh against the importance attached to reproduction cost under the rules that I have just stated, it may nevertheless be interesting to know that the courts first rejected "original cost" as a measure of present value, and first sanctioned the use of spot prices as evidently though not necessarily controlling, at the instance and urging, not of the utilities, but of the consumers. In the 1890 decade the courts had before them cases involving the valuation for rate making purposes of railroads and other utilities constructed in the

days of high prices following the Civil War. The utilities desired rates based upon those high prices and therefore argued for original cost. The consumers declared the idea of original cost to be anathema and urged upon the courts the common-sense doctrine of present value, based on the declining prices of the nineties. Their arguments prevailed, as shown by the following brief excerpts from two cases on this subject (San Diego Company against National City, and San Diego Company against Jasper), decided by the Supreme Court in 1899 and 1903 respectively. I quote from those decisions:

> The contention of the appellant in the present case is that in ascertaining what are just rates, the court should take into consideration the cost of the plant, the cost per annum of operating the plant, including interest paid on money borrowed and reasonably necessary to be used in constructing the same, the annual depreciation . . . . and a fair profit to the company . . . . . Undoubtedly all these matters ought to be taken into consideration and such weight be given them . . . . as under all the circumstances will be just to the company and to the public. The basis of calculation suggested by the appellant is, however, defective in not requiring the real value of the property . . . . to be taken into consideration. . . . . The property may have cost more than it ought to have cost and its outstanding bonds for money borrowed may be in excess of the real value of the property. (*San Diego Co. v. National City*, 174 U. S. 179, 19 Sup. Ct. Rep. 804.)

And the following:

> It is no longer open to dispute that under the Constitution "what the company is entitled to demand . . . . is a fair return upon the reasonable value of property at the time it is being used for the public. . . . . That is decided, and is decided as against the contention that you are to take "the actual cost of the plant, annual depreciation, etc., and to allow a fair profit on that footing over and above expenses." . . . . The only evidence in favor of a higher value in the present case is the original cost of the work, seemingly inflated by improper charges to that account and by injudicious expenditures. . . . . In this way the appellant makes the value over a million dollars. No doubt cost may be considered and will have more or less importance according to circumstances. In the present case it is evident . . . . that it has very little importance indeed. (San Diego Co. v. Jasper, 189 U. S. 439, 23 Sup. Ct. Rep. 571.)

And the court then proceeded to hold that the present fair value of the plant was not in excess of $350,000, against the million dollar figure urged by the Company in that case on an original cost basis.

But as you all know conditions have altered materially since the 1890's. As Shakespeare quaintly puts it "the whirligig of time brings in his revenges," and with the reversal of conditions brought about

by the World War, the people's representatives have been blind to what was so evident to them in the 1890's, the fairness and virtue of the reproduction cost theory. In the heat of conflict there is necessarily a tendency to take a short perspective in these matters, but if one takes for a moment the longer view it is not difficult to visualize the public in the 1940 decade praising the Supreme Court for not having yielded to the blandishments of the "original cost" theory in the 1920's. And, after all, how many people who built, let us say, rental properties in 1910, base their rentals today on what the properties cost them? They charge rents based on the present value of the properties. In principle this is precisely what the Supreme Court has said that the utilities are entitled to do. So much for the Supreme Court's ruling on the rules for ascertaining present value in the Indianapolis Water Company case.

II. WHAT IS A REASONABLE RATE OF RETURN ON THE FAIR PRESENT VALUE OF UTILITY PROPERTY?

Here, again, there has been some misconception of the Indianapolis Water case opinion. The Supreme Court did not fix 7 per cent as the maximum. It said that the evidence was "more than sufficient to sustain" a 7 per cent return and that "recent decisions support a higher rate of return" and it cited, among the ten decisions supporting a higher rate of return, several cases allowing 8 per cent. But the Court did not find it necessary, upon the record before it and the state of the issues, to go further than to decide that a reasonable rate of return was "not less than 7 per cent." The Court did, however, state clearly that in any utility case the rate of return cannot fairly be measured by the cost of bond money to the company. The Court said:

> It is obvious that rates of yield on investments in bonds, plus brokerage, is substantially less than the rate of return required to constitute just compensation for the use of properties in the public service. Bonds rarely constitute the source of all the money required to finance public utilities. And investors insist on higher yields on stock than current rates of interest on bonds. Obviously, the cost of money to finance the whole enterprise is not measured by interest rates plus brokerage on bonds floated for only a part of the investment.

Thus the case may fairly be cited to sustain the proposition that the rate of return depends upon "the cost of money to finance the whole enterprise."

III. MUST THERE BE IN THESE RATE CASES AN ALLOWANCE FOR WORKING CAPITAL AND MATERIALS AND SUPPLIES?

The Supreme Court in the Indianapolis Water Company case answers this question in the affirmative, in a short paragraph. It was contended by the appellants that the company was entitled to no working capital allowance because it could get its necessary working capital from pre-payments by consumers. The Court's decision, approving the allowance for working capital, rejects this contention.

IV. IS A UTILITY IN A RATE CASE ENTITLED TO AN ALLOWANCE FOR WATER RIGHTS, UPON PROPER PROOF OF THEIR EXISTENCE?

The Supreme Court holds unequivocally that it is, thus reaffirming the position that it took on this question many years ago and from which it has never departed.

V. GOING VALUE

The opinion of the Supreme Court, definitely, I think, disposes of the contention, which has been urged at various times and in various cases in the last few years, that no allowance for going value is permissible in a rate case. This argument was based—unsoundly, it is now clear,—on the Galveston and Houston cases in the Supreme Court. Those cases did reject allowances for going value, but they rejected them because the companies had attempted to base the calculation of their going value on past losses. In the Indianapolis Water Company case the Supreme Court cited several of its own earlier decisions as sustaining an allowance for going value and laid down the rule upon this subject in the language of the Des Moines gas case as follows:

> That there is an element of value in an assembled and established plant doing business and earning money, over one not thus advanced, is self-evident. This element of value is a property right and should be considered in determining the value of the property, upon which the owner has a right to make a fair return.

The court in its opinion does not attempt to lay down any rule-of-thumb for calculating the proper amount of going value in all cases but it does make some comments as to the amount properly allowed for this item to the Indianapolis Water Company which are perhaps significant as indicating generally the Court's views on this subject. After pointing out that the Commission had allowed for both water

rights and going value an amount less than 6 per cent of the value of the physical properties found by the Commission, the Supreme Court says emphatically:

> Having regard to the character of the system, that amount is clearly too low. . . . . The evidence is more than sufficient to sustain 9.5 per cent for going value. And the reported cases showing amounts generally included by commissions and courts to cover intangible elements of value indicate that 10 per cent of the value of the physical elements would be low when the impressive facts reported by the commission are taken into account.

It would therefore seem reasonably safe to believe from the opinion in the Indianapolis Water Company case that in any case where the evidence shows the existence of an assembled, established, well-managed, efficient and productive plant, the Supreme Court will approve an allowance for going value of at least 10 per cent of the value of the physical properties.

VI. CALCULATION OF DEPRECIATION

The opinion deals a death-blow to the theory of "straight-line" depreciation, which had been urged and argued for in the appellants' brief, and proves beyond question that the Supreme Court will reject large deductions based on assumed depreciations calculated on theoretical and arbitrary bases, in every case where the record contains trustworthy testimony by competent engineers who have made an actual inspection of the properties and estimates, based on their inspection, of the percentage of depreciation. The "straight-line" theory, as you know, is based on the age and the assumed life of a particular article. Thus: It is assumed that a piece of pipe will last fifty years. A particular piece of pipe is twenty years old. Therefore there must be deducted, in evaluating it, 40 per cent of its present value, regardless of its actual condition, and evidence of its actual condition is immaterial. It will certainly be useless, since the Water Company decision, to urge this "straight-line" theory. In the trial court the Water Company had presented two theories for providing for the depreciated condition of the property. One was the testimony of a competent engineer who inspected the property and based his estimate of the percentage of existing depreciation on his inspection and a consideration of the probable future life of the property as indicated by the conditions he found. The other was the testimony of a competent engineer who inspected the property and calculated the amount of money that would be required to re-

store the property to its condition when first installed. The Supreme Court's opinion does not indicate a preference for either of these two theories. Apparently it approves both; certainly it rejects *in toto* the "straight-line" method.

VII. WHAT PROPERTY IS TO BE VALUED?

Or, phrasing it differently, how far may a commission or court go, in calculating present value, in substituting for the value of the actual plant the value of a different plant which the tribunal assumes would be more efficient or more economical in operation than the actual plant? This question was presented to the Supreme Court in the Water Company case by the testimony of one of defendants' witnesses who contended that a steam plan should be substituted for the lower part of the canal at a saving alleged by the witness to be nearly $1,000,000 in value. The Supreme Court completely rejects this attempted substitution and lays down the rule that what is to be ascertained is "the value of the plant used to give the service and not the estimated cost of a different plant." This is not to say that in every case the court will permit the inclusion, in the valuation, of the property actually being used, no matter how obsolete and uselessly expensive it may be. But the Supreme Court says that "save in exceptional circumstances" it will not enter upon a comparison of the methods of different systems. It is clear, therefore, that in the ordinary case, where a utility is in good faith using a particular plant or a particular kind of machinery, the court will not permit the value of that plant or machinery to be excluded from the valuation by testimony attempting to show that some assumed substituted plant or piece of machinery would do the same work more cheaply.

I hope that I have succeeded, in what I have said, in showing the importance that the Indianapolis Water Company decision by the Supreme Court of the United States is bound to assume in future rate controversies. Practically every rate case involves the question of the method of ascertainment of present value, and the question of the proper allowance for going value. Many rate cases involve the questions of reasonable rate of return, allowance for working capital, allowance for water rights, method of calculation of depreciation and questions involving substitutions. Upon all of these questions the Water Company decision is a clear-cut precedent and it will be followed by every court and commission to which it is cited except those, if any there be, which no longer regard the decisions of the Supreme Court of the United States as the final authority.

ELECTROLYTIC CHLORINATION AT SACRAMENTO FILTRATION PLANT[1]

By Harry N. Jenks[2]

Following two and one-half years' experience in the chlorination of the Sacramento water supply with chlorine made electrolytically at the filtration plant, sufficient operating data have been obtained to present for the consideration of those interested in this special phase of water treatment.

The success attending the adoption of this method of chlorination, from the standpoint of reliability as well as of economy, suggests the possibility of there being a wide field of usefulness for what might be termed "home-made" chlorine, not only in the disinfection of water and sewage, but also in those industrial plants where a bleaching agent is required. Again, attention may be drawn to the possible advantages of home-made chlorine in remote localities, where liquid chlorine cannot be obtained at all on account of transportation restrictions. In general, conditions most favorable to electrolytic chlorine equipment are to be found in the medium sized and larger plants, and especially in those located in the West where chlorine prices are relatively high.

PHYSICAL FEATURES OF ELECTROLYTIC PLANT

Credit is due Charles Gilman Hyde, designer of the Sacramento filtration plant, for perceiving in advance the numerous advantages of electrolytic chlorination that were later realized in practice. Professor Hyde's original installation of plant and equipment has been used practically without modification, with the exception of the chlorine cells themselves, which had been purchased in the East and proved to be of incorrect design. These were in due course abandoned after the plant was enlarged, principally through the construction of six new cells designed at the filtration plant.

[1] Presented before the California Section meeting, October 29, 1926.

[2] Associate Professor of Sanitary Engineering, Iowa State College, Ames, Iowa; formerly Superintendent, Pumping and Filtration Works, Sacramento, California.

The essential component parts of a complete electrolytic chlorinating plant comprise:

a. Salt storage room
b. Brine saturator
c. Brine filter
d. Brine storage tanks
e. Electrolytic cells and appurtenances
f. Chlorine ejectors and piping
g. Direct current generating apparatus
h. Chlorine control panel board

Salt storage room. At the Sacramento plant, commercial rock salt is stored in a concrete bin in the basement of the head house. Its capacity is roughly 30 tons of salt. For calculation of storage space required, the weight of salt may be taken at 72 pounds per cubic foot.

Brine saturator. The saturator at Sacramento is built in the form of a relatively deep, rectangular, concrete tank, divided by a partition wall into two compartments. One of these serves as a holder for the salt, through which water is allowed to percolate upward from a perforated pipe laid close to the hopper bottom. The other compartment receives the overflow from the first as the brine passes over the top of the partition wall, and serves as a storage tank for the brine prior to filtering. A certain amount of sludge settles to the bottom which may conveniently be removed by flushing through a drain opening, at a time when the tank is empty.

The saturator is capable of dissolving as much as 4000 pounds of salt per twenty-four hours, yielding about 500 gallons of brine of 1.2 specific gravity. The required capacity of a saturator may be computed, according to experience, on the basis of 0.6 gallon for each gallon of brine per twenty-four hours it is desired to furnish.

Brine filter. If a filter on the slow sand principle is used, it will be found that frequent scrapings of the sand must be resorted to if the rate reaches 0.1 gallon per square foot per minute, and occasionally the sand has to be completely replaced. Accordingly, a miniature rapid sand filter is to be recommended, such as the one now in use at the Sacramento plant, which may be operated at the usual rate of 2 gallons per square foot per minute. The filter is provided with three $1\frac{1}{4}$–inch perforated pipe laterals discharging into the brine pump sump and embedded in a cemented gravel slab on which 18 inches of filter sand rests directly. An occasional washing of this

filter keeps the sand in excellent condition. A float-operated valve maintains a constant level on the filter as the brine comes from the saturator.

The brine pump is an all-iron, centrifugal pump, direct-connected to an electric motor. Its operation has been entirely satisfactory and no corrosion has been noted.

Brine storage tanks. The brine storage tanks may be made of any convenient size suited to local conditions of operation, but in general they should be in duplicate to allow brine to settle in one while the other is in use. A storage period of two days should ordinarily be satisfactory.

At the Sacramento plant, each of the two storage tanks has a capacity of 500 gallons, the brine being pumped into them and thence flowing by gravity through the brine manifold pipe feeding the cells. A float-controlled angle valve in a small, lead-lined box maintains the required flow from the tanks into the individual chlorine cells.

Electrolytic cells. The design of the cells is characterized by unusual strength and simplicity, and represents the embodiment of numerous excellent ideas and methods gathered by Charles Lundelius, Chief Coagulant Plant Operator, Sacramento filtration works, through many years' experience in the commercial production of chlorine in eastern manufacturing establishments.

The installation consists of six 600-ampere cells mounted in a row as shown in figure 1. The installation is out-doors, the operation being unaffected by the California weather, and any accidental discharge of chlorine is quickly dissipated in the atmosphere. In colder climates, it would be desirable to place a roof over the cells, the actual amount of protection needed being governed primarily by the necessity of keeping the electrolyte and effluent from freezing. In any case, the external temperature should not be so low as to decrease materially the temperature of the electrolyte inside the cells below 70° to 80°C., which is desirable for good operating efficiency.

It may be noted at this point that the space occupied by the cell units is relatively small, so that a large sized plant may be constructed without providing an undue amount of space. In this respect the plant is on a comparable basis with the standard chlorinator installation where room must be allowed for the machines, the weighing scales, and chlorine cylinder storage.

Cell body. The cell body is made of reinforced concrete, the proportions being 1:1:1 of cement, sand and pea-gravel, respectively.

The main casting is in the shape of a "U" with prolonged base. The form for the cells was in reality a wooden pattern for casting the concrete, the general arrangement of the component parts of the form

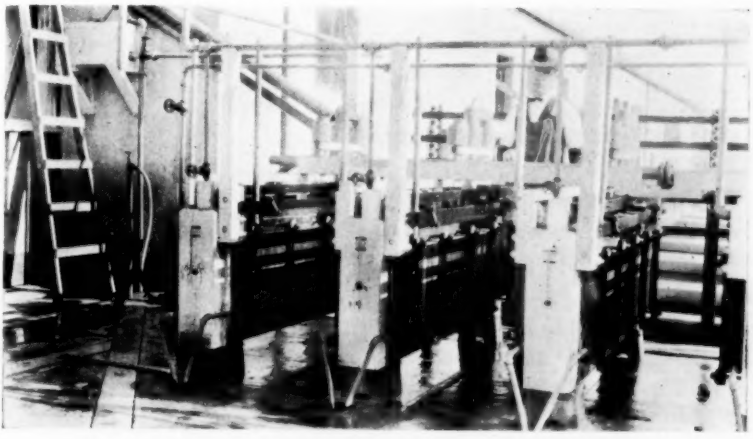

FIG. 1. GENERAL VIEW OF CHLORINE CELL INSTALLATION

FIG. 2. POURING CELL BODY, SHOWING TYPE OF FORM EMPLOYED

and method of pouring the concrete being indicated in figure 2. The same wooden form was used for each of the cells in turn. A cell could readily be poured in 2 hours and the form could be removed after 12 hours and used on the succeeding cell.

The sides of the cell body were dressed with carborundum bricks to make a plane surface of contact between them and the effluent side pans. A rubber gasket for this purpose or else several thicknesses of asbestos paper glued on around the perimeter of the pan, has been found satisfactory.

The top side pieces of the cell are cemented in after the U-body has set. Spacer blocks serve as compression members to take the thrust of cinching up the bolts passing through the side pieces and serving as anchorages for the steel straps fastening the effluent boxes against the sides of the cell.

The interior of each cell is free from all obstructions, thus permitting the ready insertion and withdrawal of the carbon anode plates. These are supported on the bottom of the cell and the posts extend upward through the cell cover which is made in sections and sealed in place by means of a coal-tar and china-clay putty. Or else a battery-sealing compound in suitable for this purpose. A view of the various features of the cell body just enumerated is shown in figure 3.

It should be noted that the negative bus bar is attached directly to the cathode plate with ample cross-sectional area of metal to transfer the current without loss. All electrical connections are external to the cell, making them accessible, and free from attack by the chlorine.

Electrodes. The carbon anodes are built-up members, consisting of four plates each attached to a square, vertical post, into which is screwed a round carbon rod extending through the cell top and forming the connection with the positive bus bar. The plates are secured to the post by tapered carbon pins driven to a snug fit and assuring an intimate contact between the surfaces of the plates and the post. The general design of the cell is such that electrolysis of the electrodes is greatly retarded. A view of the anode assembly is shown in figure 4.

The carbons were obtained from the Acheson Graphite Company, Niagara Falls, N. Y. The graphitized carbon product manufactured by this company is made especially for electrolytic cells and is of a uniformly high quality.

The cathode plates are secured to the cast iron effluent pans by machine screws and are flat, thus premitting the asbestos diaphragm to be easily laid across the plate and secured thereto. The method of mounting the cathode plates permits quick renewal of the diaphragms, a design feature that is in most instances very poorly at-

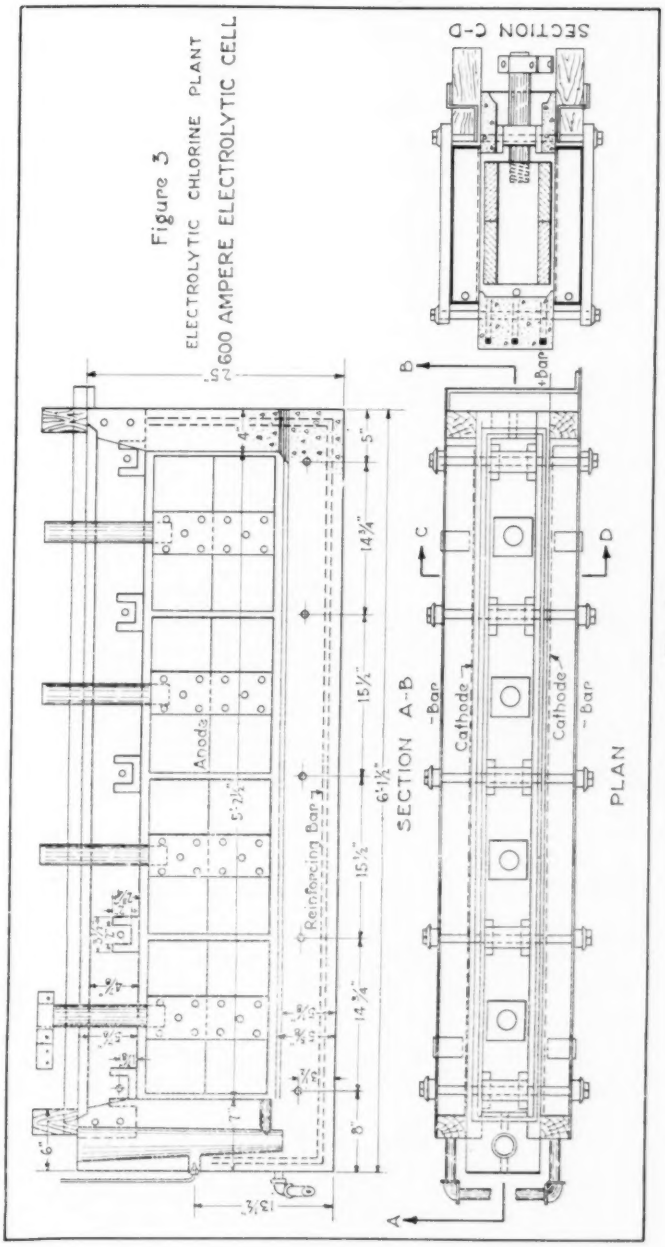
Figure 3
ELECTROLYTIC CHLORINE PLANT
600 AMPERE ELECTROLYTIC CELL
SECTION C-D
SECTION A-B
PLAN
Anode
Reinforcing Bar
Cathode
Bar
A
B
C
D
4"
5"
14¾"
15½"
15½"
14¾"
8"
7"
6"
6½"
13½"

FIG. 3

tended to. No disturbance of any other parts of the cell is occasioned by the removal of the diaphragm, and, conversely, the paper may be replaced without any danger of tearing or sagging.

The cathode plates were furnished by the Hendrick Manufacturing Company, Carbondale, Pa., makers of perforated metals. The specifications called for: Screen plates, No. 16 U. S. gage steel, with $\frac{3}{16}$ by 1 inch slots in straight lines, $\frac{3}{16}$ inch side bar and $\frac{1}{8}$ inch end bar.

These plates were cut to dimensions, with margins and holes drilled for fastening to the effluent boxes. The manufacturers produce a grade of steel plate well suited to the requirements of electrolytic cell design.

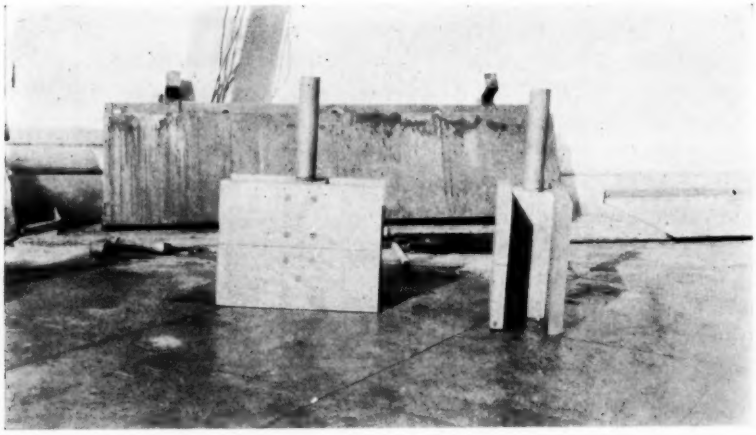

FIG. 4. VIEW OF ANODE ASSEMBLY AND CATHODE PLATE (BACKGROUND)

The asbestos paper used for diaphragms is obtainable from the Johns-Manville Company. It is a special, long fiber asbestos paper of 12 pounds per 100 square feet weight, the thickness being approximately 0.025 inch. This paper is placed, doubled, over the perforated cathode plates. It gives excellent service, the percolation being satisfactory up to the time the paper needs changing on account of lowered current efficiency due to excessive caustic soda concentration in the effluent.

Chlorine manifold and ejectors. As will be noted from the photograph in figure 1, showing a general view of the chlorine cells, the chlorine manifold is made of chemical lead pipe, with lead jumper pieces to allow the gas from any of the cells to enter either the raw

water or filtered water discharge line. The cups on the risers from the cells and on the T-connections with the header pipes, contain water seals.

The chlorine manifold piping entails considerable lead-burning if made according to the Sacramento design. In certain instances, either hard rubber or stoneware piping might prove to be more feasible and economical.

The gas is removed from the cells by an ejector on each of the two dosing lines provided. Experience with chemical lead-lined ejectors proved the lead to be subject to excessive corrosion, due, it is presumed, to the combined action of the chlorine and the ejector water, the latter containing considerable carbon dioxide and dissolved oxygen. In replacing the orignial lead-lined ejectors, it was found that an ejector of cast iron throughout, withstands all chemical and mechanical deterioration in a very satisfactory manner. The machine work in making the cast iron ejector was done in the plant machine shop. Hard rubber and stoneware ejectors are equally durable, but are more expensive.

Labor of assembly. The labor expense of constructing one 600-ampere cell having a capacity of 38 pounds of chlorine per twenty-four hours should be very closely as follows:

Machinist	3 days @ $8.00	$24.00
Electrician	3 days @ $10.00	30.00
Pipe-fitter	2 days @ $8.00	16.00
Helper	2 days @ $6.00	12.00
		$92.00

For a larger plant, the actual labor item per cell would be correspondingly reduced.

It is assumed that the work would be done under the direction of a competent designer, whose time should be charged against the job, in whole or in part, according to circumstances.

Direct-current generating apparatus. The original equipment comprised duplicate 300-ampere motor-generator sets. When the chlorine plant was enlarged, a new 600-ampere set was installed. All three units were furnished by the Westinghouse Electric and Manufacturing Company. In connection with the 600-ampere apparatus, the specifications called for a 25 h.p., 3-phase, 60-cycle, 220-volt, squirrel cage induction motor of 40 degrees rating, operating at 1160 r.p.m., direct-connected by flexible coupling to, and mounted on a

common cast iron bed plate with, one 600 ampere, 10 to 25–volt, 1160 r.p.m., direct-current generator of not less than 15 kw. capacity

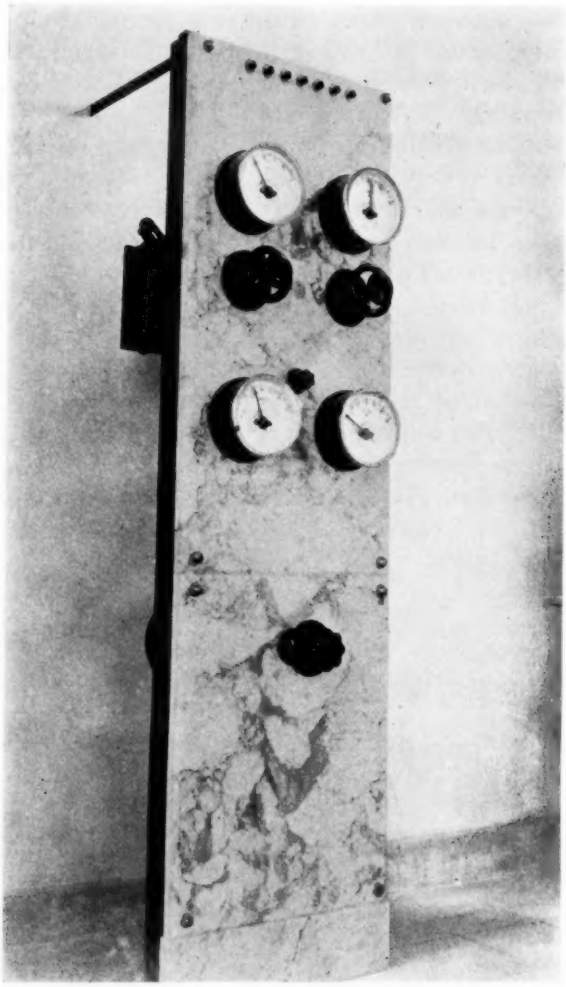

FIG. 5. ELECTRIC CONTROL PANEL BOARD FOR REGULATING CHLORINE DOSE

and capable of delivering full 600 amperes at any voltage from 10 to 25 volts inclusive

Chlorine control panel board. The control equipment for regulating the chlorine dose is located in the filter gallery, as shown in figure 5.

In the immediate vicinity of this control board is another panel upon which the master rate-of-filtration gage is mounted. The filter operator upon reading this gage, consults a chart which gives him the number of amperes at which to operate the cells in order to produce the quantity of chlorine required by the given dose and the amount of water to be treated.

It is the practice to adjust the amperage to the water consumption each half-hour. For any given setting, the current remains constant without any need for adjustment. Signal lights correspondingly to each of the six cells are mounted in a row near the top of the panel and enable the operator to observe from any part of the filter gallery whether the required number of cells is in service. Recently, a siren was installed to give immediate warning whenever a power interruption occurs.

GENERAL CONSIDERATIONS RELATING TO OPERATION

Dependability of operation. Among the chief requirements of a plant of this character is the uninterrupted functioning of the chlorine cells. Experience shows that if the cell installation is divided into a sufficient number of units with at least one cell in reserve, and with proper operation, no failure in chlorine dose need be feared on account of the breakdown of the cells themselves. The probability of the entire plant going out of commission at once is very remote. Evidently only the matter of the need for occasionally stopping the motor-generator set for cleaning or repairs, if but one set is used, and of the failure of power even if duplicate sets are installed, gives rise to the question of the advisability or necessity of providing standby liquid chlorine equipment.

Local conditions affecting the problem of treatment of the water supply or sewage disposal plant effluent will govern in the matter of standby apparatus. Assuming that the highest degree of certainty of uninterrupted service is essential, the question of what type of duplicate equipment shall be installed may be considered from the standpoint of the economics of the situation.

At Sacramento, the motor-generator apparatus is in duplicate, not only insuring reliability, but also great flexibility of operation. The plant has also a standby standard chlorinating apparatus which may be used during prolonged power interruptions or if for any reason the entire cell installation has to be shut down for repairs. Neither of these contingencies has so far occurred.

If liquid chlorine is available, a standby chlorinator may prove to be more economical than a duplicate motor-generator set. In that case a certain number of chlorine cylinders should be purchased outright to avoid storage charges on the emergency reserve supply of chlorine kept at the plant.

On the other hand, if electric power interruptions can be practically eliminated, it would appear better to install duplicate d.c. generator equipment and dispense with the use of liquid chlorine entirely. If there is a large seasonal or even daily fluctuation in the amount of chlorine required, resulting in a widely varying load on the d.c. generator, the economy of using smaller generator sets should be investigated in connection with the selection of duplicate apparatus. Thus on a 600–ampere circuit, the standby equipment might advantageously consist of two 300-ampere motor-generator sets, arranged to run either separately or in parallel.

Practical efficiency of d.c. generation. A recent study of the over-all efficiency of the motor-generator sets showed clearly that they should be operated as nearly up to full d.c. load as possible. Otherwise the current consumption for power on the a.c. side will considerably exceed the useful current producing electrolysis.

An interesting fact also demonstrated by these tests is that, for a given per cent of full load on the d.c. circuit, higher efficiencies are attained throughout the normal range of operation when a greater number of cells are in the circuit. That is, the efficiency in general is increased when the total electrical input into the cells is composed of less amperes at a higher voltage. The practical application of this principle is to operate, when a choice exists, say two cells at 300 amperes rather than one cell at 600 amperes. In either case the amount of chlorine produced is the same. This saving in power, however, may be more than offset by the resulting increased use of salt per pound of chlorine evolved, as will be noted in a succeeding paragraph.

The results of the tests just described are embodied in the form of efficiency curves in figure 6, in which the per cent efficiency is plotted against per cent of full load. The per cent efficiency at the given load is the ratio of the direct-current output to the alternating-current input. It will be observed that the highest efficiency for the 600-ampere set was 75 per cent at 70 per cent full d.c. load; while for the 300-ampere set, the highest efficiency was 70 per cent at full load. In both cases 5 cells were in the circuit.

Utilization of Electrolyte. The brine consumption, which is a measure of the amount of salt used, varies considerably per pound of chlorine produced, on account of the impracticability of operating all the cells at full capacity continuously. When a cell is not working to capacity, the brine percolates through the diaphragms at the full

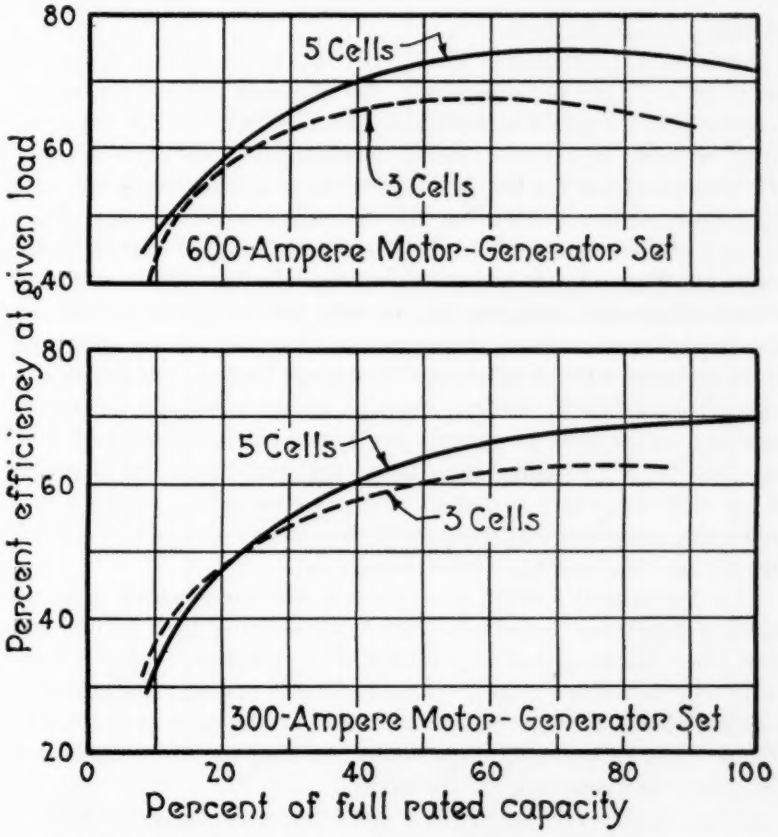

FIG. 6. EFFICIENCY OF MOTOR-GENERATOR SETS IN RELATION TO DIRECT CURRENT LOADING

rate just the same, and is wasted to the extent that it has not been electrolyzed, in its passage through the cell.

In the operation of electrolytic cells, it is not practicable to obtain much more than a 50 per cent decomposition efficiency of the brine. At this efficiency the minimum salt requirement is approximately 3.33

pounds per pound of chlorine generated. Under actual operating conditions, involving a variable load, sufficient brine goes to waste to increase the salt consumption as much as 50 per cent. At Sacramento, during the present year, the salt consumption averaged 4.60 pounds per pound of chlorine, or 38 per cent above normal. Except in special cases, it would not be economical to recover the excess brine passing through the cells.

Sustained cell efficiency. The merits of any particular design of electrolytic cell are to be judged by the efficiency that is attained in practice, and the use of correct principles is reflected in the dependability, economy and convenience of operation. Of the three customary tests involving the use of current, the power requirements, and the decomposition of the brine, the basic consideration is that of the current efficiency, especially in the chlorination of public water supplies. That this is so is evident from the fact that the actual weight of chlorine delivered by the cells for any given current in amperes is based on the tacit assumption that the cells are operating at 92 per cent current efficiency or slightly higher. Although the true current efficiency as such must be tested from time to time as indicated in the next paragraph, yet it may safely be assumed that the efficiency will remain close to the required amount if the condition of the cells as a whole is normal. Such a condition is reflected in a well sustained electrical efficiency of the cells as revealed by testing the voltage requirements of the installation.

This last-named feature of operation was investigated after 10 months' continual operation under loads varying from 100 to 600 amperes. The results of this test are given in figure 7. The voltage requirements, being a measure of the resistance of each cell, constitute a good indication of the general conditon of the cells in relation to the necessity of changing diaphragms, cleaning out the sludge accumulations, and renewing the electrodes.

In the diagram, points on each ordinate representing 100 ampere increments in current were obtained from the average of 4 observations on each of 4 cells. It is seen that the typical voltage curve is essentially a straight line; that is, the resistance increases directly with the current. The point at which the line crosses the ordinate of zero current is termed the critical voltage. In this case it is 2.24 volts and is a measure of the counter E.M.F. of the electrolyte.

Referring again to figure 7, a curve has been drawn to show the volts required by the electric circuit only, under actual conditions of plant operation. This includes the effect of all electrical losses between the

motor-generator sets and the electrolytic cells, including the connections to the anodes of the latter. From a consideration of both curves of figure 7 the actual electrical load on the d.c. generator can be estimated.

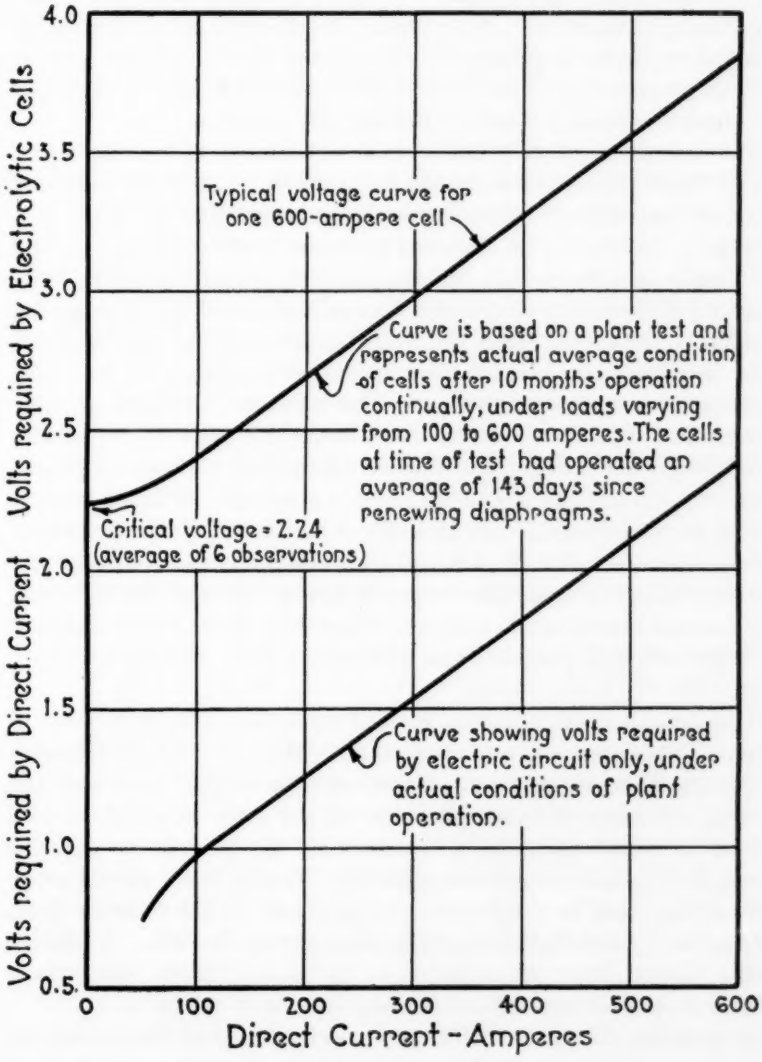
Volts required by Direct Current
Volts required by Electrolytic Cells
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
100
200
300
400
500
600
Direct Current - Amperes
Typical voltage curve for one 600-ampere cell
Curve is based on a plant test and represents actual average condition of cells after 10 months' operation continually, under loads varying from 100 to 600 amperes. The cells at time of test had operated an average of 143 days since renewing diaphragms.
Critical voltage = 2.24 (average of 6 observations)
Curve showing volts required by electric circuit only, under actual conditions of plant operation.

FIG. 7. VOLTAGE REQUIREMENTS OF ELECTROLYTIC CHLORINE CELLS AND VOLTAGE DROP THROUGH D. C. CIRCUIT FROM MOTOR GENERATOR SET

Regulation of chlorine dose. As far as the filter operator's work is concerned, the amount of chlorine fed into the water is varied simply by turning a rheostat handwheel mounted on the chlorine control panel board, as shown in figure 5. The reading on the ammeter corresponds with the dose in parts per million and the rate of filtration in million gallons daily. As previously noted, such simple regulation is based on the assumptions that the amount of chlorine generated is directly proportional to the current passing through the cells, and that the current efficiency remains substantially constant.

The first assumption is based on an acceptance of Faraday's first law of electrolysis a statement of which may be found in any standard work on the subject. This law states in effect that the mass of a substance liberated at an electrode is proportional to the current and the time. In other words, the amount is dependent upon the total quantity of electricity that passes through the electrolyte. Applying this law to the present case, the weight in grams of chlorine liberated from the brine equals a constant times the coulombs of electricity supplied (=amperes per second). The constant is termed the electrochemical equivalent, which for chlorine has been determined as 0.0003675. Accordingly one ampere flowing for one second (=one coulomb) will liberate 0.0003675 gram of chlorine. Making the necessary computations to convert this value into terms of pounds of chlorine per 24 hours, it is found that 600 amperes of current will produce 41.9 pounds of chlorine per 24 hours. In practice, however, this amount is reduced to 38.5 pounds per day, under the assumption that the cells will operate at an average current efficiency of 92 per cent.

This second assumption is verified by actual test from time to time. The efficiency of a cell immediately after changing diaphragms will reach 95 to 97 per cent. Experience shows that thereafter the current efficiency will not fall below 92 per cent during the useful life of the diaphragms, as determined by the percolation and the strength of caustic soda in the effluent. Usually there should be no serious objection to a tolerance of 4 per cent in the chlorine dose, occasioned by the slightly variable efficiency of the cells. At Sacramento, dosing charts are prepared on the basis of 92 per cent current efficiency, so that any deviation is on the side of safety.

In practice, the current efficiency is determined by comparing the amount of sodium hydroxide appearing in the effluent with that which the current passing through the cell at the time of the tes

should theoretically produce. From the efficiency so found, the actual amount of chlorine generated may be checked by computation, since the formation of caustic soda and the gas is always on a strictly equivalent basis. The efficiency test should be made at least once a week, and can readily be included in the routine laboratory control of the water or sewage treatment plant. The test is quite simple and reliable, as further noted in the discussion of this paper by Mr. Lundelius.

ELECTROLYTIC CHLORINE COST DATA

Cost of construction of plant. A detailed analysis of the cost of the electrolytic chlorine plant and appurtenances installed at the Sacramento filtration plant is given in table 1. For convenience of reference, the items are grouped under four main headings with corresponding sub-total costs. Except for some of the original equipment installed under contract, the cost figures in general represent closely the actual known expenditures for the various items. It is seen that the total investment is $8171, resulting in a cost of $35.80 per pound of chlorine capacity with duplicate motor-generator sets, and a corresponding cost of $27.10, omitting duplicate d.c. current equipment.

Depreciation allowances. According to experience so far gained through the operation of the plant at Sacramento during the past year it appears that the depreciation of equipment shown in table 2 should be on the side of safety:

Annual fixed charges. Applying the factors for depreciation as given in table 2, to the corresponding initial costs of the component parts of the plant, the following total depreciation charges are obtained, to which are added the interest charges on the investment in determining the total annual capital expense, as set forth in table 3.

In connection with the unit cost per pound of chlorine resulting from the capital investment, it is obvious that the value of 1.64 cents cannot be attained in practice, due to the fact that the plant will not be operated up to its full capacity continuously. The economic plant size in relation to the variations in chlorine demand therefore requires a special study in each instance.

Operating costs. The costs of operation may be grouped into three general classifications:

a. Electric current
b. Salt
c. Supervision

TABLE 1

Analysis of cost of electrolytic chlorine plant installation with 228 pounds per 24 hours rated plant capacity

1. *Brine equipment:*		
Salt storage room	$300.00	
Brine saturator and equipment	300.00	
Brine filter and pump sump	150.00	
Pumping unit, storage tanks and appurtenances	550.00	
Brine lines and miscellaneous piping	200.00	$1,500.00
2. *Electrical equipment:*		
2 600-amp. 10–25 volt. d.c. motor-generator sets installed complete	$4,000.00	
Electric wiring and control equipment	800.00	4,800.00
3. *Chlorine lines:*		
Manifold piping	$200.00	
2 Chlorine ejectors	75.00	275.00
		$6,575.00
4. *Electrolytic chlorine cells:*		
Form for cell body	$15.00	
Concrete and steel for body	15.00	
Cell cover	5.00	
4 Anode assemblies @ $13	52.00	
2 Cathode perforated plates @ $3	6.00	
2 C.I. effluent pans at $15	30.00	
2 Asbestos diaphragms	1.00	
Electrical connections	20.00	
Miscellaneous iron work; bolts, etc	25.00	
Supports and painting	5.00	
	$174.00	
Labor of assembling	92.00	
	$266.00	
× 6 cells =		1,596.00
Total cost of electrolytic chlorine plant		$8,171.00
Capital investment per pound of chlorine capacity		$35.80
Ditto, omitting Duplicate Motor-Generator Set		27.10

The electric current paid for is measured on the a.c. side of the motor-generator equipment by a watt-hour meter, which is read at the end of each month. Except for times when the load falls con-

TABLE 2

Schedule of chlorine plant depreciation

ITEM	PROBABLE USEFUL LIFE	STRAIGHT LINE ANNUAL DEPRECIATION
	years	*per cent*
1. Brine equipment	20	5
2. Electrical equipment	25	4
3. Chlorine lines	5	20
4. Electrolytic cells		
a. Cell body	5	20
b. Cell cover	1	100
c. Anode assembly	2	50
d. Cathode plate	1	100
e. Effluent pan	5	20
f. Diaphragm	¼	400
g. Electrical connections	2	50

TABLE 3

Annual fixed charges, electrolytic chlorine plant, Sacramento, California

ITEM	COST	ANNUAL STRAIGHT LINE DEPRECIATION	
		Per cent	Total
1. Brine equipment	$1,500	5	$75.00
2. Electrical equipment	4,800	4	192.00
3. Chlorine lines	275	20	55.00
4. Electrolytic cells	1,596	39.7*	634.00
	$8,171	11.7†	$956.00
Assume interest charges at 5 per cent (0.05 × $8,171)			$408.55
Total annual fixed charges			$1,364.55
Capital cost of chlorine on basis of full plant production, per pound of chlorine‡			$0.0164

* Weighted average depreciation, including labor.

† Weighted average plant depreciation per year for entire plant.

‡ Plant capacity equals 228 pounds chlorine per 24 hours, or 83,220 pounds per year.

siderably below normal and the consequent efficiency of a.c.–d.c transformation is reduced, as previously shown in figure 6, the amount of current required per pound of chlorine is quite uniform, the average being 2.66 kilowatt-hours.

TABLE 4

Summary of actual cost of manufacture of electrolytic chlorine at Sacramento Filtration Plant

ITEM	PER POUND OF CHLORINE
	cents
Capital charges*	1.64
Operating cost:	
Electric current	2.30 } 4.02
Salt	1.72 }
Total	5.66

* Based on continuous operation at full plant capacity of 228 pounds chlorine per 24 hours.

TABLE 5

Analysis of cost of chlorination with liquid chlorine in comparison with that of electrolytic chlorination

Liquid chlorine apparatus:	
2 Standard type chlorinators, with appurtenances, installed	$3,200.00
1 Indicating dial chlorine scales	300.00
	$3,500.00
Allowing 10 per cent yearly depreciation and 5 per cent interest on investment, annual capital charges equal	525.00
Liquid chlorine, purchased in 150-pound cylinders at base price of 12.5 cents per pound	

Summary of comparative unit costs per pound of chlorine

	COST PER POUND OF CHLORINE
	cents
Liquid chlorine apparatus, annual fixed charges*	0.63
Liquid chlorine, operating cost	12.50
Total	13.13
Electrolytic chlorine, total cost	5.66
Saving per pound of chlorine by electrolytic method	7.47
Per cent saving over liquid chlorine	57%
Estimated actual annual saving on basis of operation at full plant capacity, equals $0.0747 × 83,220 pounds	$6,220.00

* On basis of 228 × 365 = 83,220 pounds chlorine dosed per year.

Due to the relatively large block of electric energy purchased by the City for the operation of the pumping station, the electrolytic chlorine plant has the benefit of the low unit cost of current of approximately 0.865 cent per kilowatt-hour. Accordingly, the total cost for current becomes 2.30 cents per pound of chlorine produced.

In reference to the salt consumption, it has been found from a study of the actual amount of salt weighed into the chlorine plant, that the average quantity required is 4.60 pounds per pound of chlorine produced. The corresponding total cost for salt therefore becomes 1.72 cents, taking salt at $7.50 per ton delivered into the storage bin.

The supervision of the plant is part of the regular duties of the filter operators. The amount of time required and the skill of the operator is in no essential different from what is needed in the operation of standard chlorinating apparatus. Occasional assistance is required in making repairs and renewals, but this cost has been included in the item of depreciation.

Summarizing the actual outlay for capital charges and for materials and supplies for operation, table 4 is submitted.

A comparison with the cost of a conventional chlorinator installation, using commercial liquid chlorine, is given in table 5. To place the two different types of plant on a comparable basis of reliability of operation, it is assumed that two chlorinators would be installed, one of these corresponding to the duplicate motor-generator set and appurtenances provided in the electrolytic plant.

CONCLUSIONS

A consideration of the foregoing cost analyses shows clearly that, from the standpoint of expense, the advantage of electrolytic chlorination is dependent primarily on there being a substantial margin between the market price of liquid chlorine and the actual cost of production locally at the treatment plant, a condition that prevails in the West. The writer is aware that in the Eastern market, chlorine commands a price of perhaps 5 to 7 cents per pound, so that electrolytic chlorination could not there compete on the score of cost. Accordingly the reasons for its adoption would have to be based on the favor with which other features of this method might be regarded.

There would doubtless be instances where choice of methods would rest largely upon the judgment of the designer as to which constituted the more desirable one from the standpoint of operation.

The writer is not inclined to press the claims of electrolytic chlo-

rination from this point of view any more than those of liquid chlorine application, because from his experience with each method, both independently and jointly, there appears to be as much to say in favor of one as of the other.

Yet at the Sacramento plant, the electrolytic method has greatly reduced the cost of chlorination, and is much preferred in respect to the ease of control of the chlorine dose and the elimination of the handling and weighing of chlorine cylinders.

In conclusion, it is believed that the experience at Sacramento proves in a convincing manner that the manufacture of electrolytic chlorine in conjunction with the operation of a modern water filtration plant, sewage disposal works, or industrial establishment is thoroughly feasible, and may often be of decided economic advantage in effecting a substantial saving in the cost of chlorination, especially on the Pacific Coast.

DISCUSSION

CHARLES LUNDELIUS[3] (by letter): In elaborating somewhat on Professor Jenks' paper on the use of electrolytic chlorine in the treatment of the Sacramento water supply, it may be of interest to review very briefly the historical development of the present type of chlorine cells.

The chlorine of commerce is obtained from sodium chloride (common salt) by means of some electrolytic process. As the electrolysis of brine on a commercial scale is comparatively new, it is often looked upon as something mysterious, to be attempted only by the initiated. As a matter of fact, however, few manufacturing processes are as simple.

The essential requirements of an electrolytic cell include merely a pair of electrodes and the passage of a direct current of electricity between them, in a solution of salt in water. The primary products formed in so simple a cell, however, would immediately enter into secondary reactions, and not be available as desired. The primary products referred to comprise negatively charged chlorine ions and positively charged sodium ions. The former release their negative charges upon coming in contact with the anode and are liberated as free chlorine gas. At the cathode the sodium ions give up their

[3] Chief Coagulant Plant Operator, Sacramento Pumping and Filtration Works, Sacramento, Calif.

positive charge and immediately react with the water of the electrolyte to form sodium hydroxide (caustic soda), at the same time liberating hydrogen from the water molecule. The aim of the various cell designs has always been that of removing these substances, chlorine, caustic soda and hydrogen, from the zone of electrochemical activity as rapidly as they are formed, thus avoiding the secondary reactions that lower the cell efficiency and are destructive to the cell itself.

In an effort to accomplish this result, designers have continually changed the physical arrangement of the cells, until perhaps the greatest advance was made in this respect when, about 1890, Gresheim designed a cell having a porous diaphragm intended to remove the sodium ions as fast as formed. Though it solved this problem, the process could not be carried on continuously; when about one-third of the salt had been decomposed, the cell had to be shut down and the brine renewed. Other types followed in quick succession, so that it is difficult to state who first developed the present type of diaphragm cell.

In general, these cells are made of concrete, comprising a bottom and two ends, roughly forming a "U." Inside of this frame are placed carbon plates forming the anodes. These project above the cell covers and are connected in parallel to the positive bus bar. Against the two open sides are placed a perforated steel plate covered with asbestos paper. The plate forms the cathode while the paper is the diaphragm. When a current is passed through the cell, chlorine is liberated at the anode and is drawn off as fast as formed through a hole in the cover, while the sodium migrates to the cathode. The sodium passes through the diaphragm in the ionic state, but on coming in contact with the cathode plate becomes metallic sodium which reacts with the water of the brine to form NaOH and hydrogen, outside of the portion of the cell containing the electrolyte. Accordingly the caustic is removed in the effluent and the hydrogen escapes to the atmosphere through suitable vents in the effluent pans. As this operation proceeds over a period of two or three months, the asbestos paper becomes clogged by impurities in the brine and needs to be renewed. This is a matter of cell upkeep and is a simple and inexpensive item.

In operation, the cells require no other attention than to see that the brine does not fall below the top of the diaphragm and that a constant suction of about $\frac{1}{8}$-inch of water is maintained, in order

to remove the chlorine gas from the cell as fast as it is produced. Occasionally, also, the electrical connections to the carbon posts require cleaning and tightening up.

TABLE 6

Determination of electrolytic chlorine cell efficiencies

Note amount of current in amperes passing through the cell.

Hold current constant at least 15 minutes before taking sample of effluent. Collect a one-minute sample of the effluent. This amount, multiplied by 60, gives the percolation per hour.

Then draw off 10 cc. of the sample into a suitable flask, dilute with water and titrate with N/1 H_2SO_4. The number of cubic centimeters of sulphuric acid used, multiplied by 0.04 (normal factor for NaOH) gives the amount of NaOH in grams, in the sample titrated. By proportion, determine the weight of NaOH appearing in the effluent during one hour.

Multiply current noted above, by 1.494 (= NaOH in grams produced by one ampere in one hour), to obtain the weight of NaOH that should be produced at 100 per cent current efficiency, during one hour.

The actual amount of NaOH produced divided by the theoretical amount (for 100 per cent efficiency) gives the actual current efficiency at the time of the test.

Example:

Current = 600 amperes × 1.494 = 896.4 grams NaOH per hour.
Percolation = 150 cc. per minute = 9000 cc. per hour.
10 cc. sample required 23.0 cc. N/1 H_2SO_4.

Then 23.0 × 0.04 = 0.92 gram NaOH
Whence amount produced = 0.92 × 9000/10 = 828.0 grams NaOH per hour

Therefore Current Efficiency = 828/896.4 = 92.3 per cent

If the voltage required should be, say, 3.6 volts
Then 2.3/3.6 = 63.9 per cent = Power Efficiency
And 63.9 per cent × 92.3 per cent = 59.0 per cent = Energy Efficiency

If the brine should contain 317.9 grams NaCl per liter (equivalent to 2.64 pounds per gallon @ sp. gr. 1.2)
And the effluent should contain 158.9 grams NaCl per liter
Then 158.9/317.9 = 0.50 or 50 per cent = Decomposition Efficiency

The voltage required when the cell is new is generally between 3.2 and 3.5 volts. This will gradually increase due to increased resistance of the anodes and electrolyte resulting chiefly from secondary reactions and the presence of impurities. The voltage should not be

allowed to rise much above 4.0 volts, when the anodes should be examined and, if necessary, renewed in whole or in part.

In a cell of 600–ampere capacity, about 9000 cc. of effluent should percolate through the diaphragm per hour. This will give a caustic strength of between 7 and 8 per cent. In any case, the percentage of caustic should never be allowed to rise above 11 per cent, as the percolation then would necessarily be too low to carry off the sodium ions, which would in turn remain in the electrolyte and cause secondary reactions, forming sodium hypochlorite, chlorate and perchlorate. The cell efficiency is thus reduced as both sodium and chlorine are lost as far as availability for the purposes desired is concerned. The remedy is to renew the diaphragms.

The brine is a salt solution of approximately 25 per cent NaCl, having a specific gravity of 1.2. In commercial installations, the brine should be purified to eliminate Na_2SO_4 and Na_2CO_3, and it is also customary to have it either slightly acid or alkaline. How much of this treatment is warranted depends upon circumstances. In general, the purer the brine is, the longer the diaphragms will last. In practice, in installations of the sort under consideration, it is sufficient simply to pass the brine through a sand filter. Finally, as the resistance of an electrolyte decreases with the temperature, it is well to keep the temperature high, or from 70° to 80°C.

If it is desired to operate the cells at the highest efficiency, as in commercial installations, daily tests must be made of the composition of the effluent, and the loss of voltage across each cell should be observed. These tests are quite simple, in practice the voltage being read and recorded each time the chlorine dose is regulated; and the effluent is titrated by the chemist at pre-determined intervals. In connection with the treatment of water with the chlorine produced, the test for caustic in the effluent may properly be made once a week, and, as Professor Jenks states in his paper, may conveniently be made a part of the routine laboratory control of the water purification works.

As already stated, the cell efficiency may be determined by measuring the amount of caustic soda contained in the cell effluent, from which the actual amount of chlorine being produced at the time may be accurately computed, on the basis of their chemical combining weights. In the determination of electrolytic cell efficiencies, table 6 is given as illustrative of the general method and the laboratory procedure to be followed.

THE DENVER FILTER PLANT

By James H. Fuertes[1]

The new 64-million gallon Marston Lake Water Purification Plant put into operation in August, 1925, at Denver, Colorado has many novel and interesting features. The process is that of rapid filtration preceded by screening, aeration, coagulation and accompanied by sterilization.

The works consist of an intake, screening plant, aerators, mixing chambers, coagulation basin, rapid filters, clear water reservoir and a boiler pump and head house containing the mechanical equipment, heating boilers, coagulant storage, storage facilities for wash water, high pressure water and air. The water treated is drawn from Marston Lake which in itself is fed largely from the South Platte River.

CHARACTER OF WATER

The results from the filtration of Marston Lake water are very good, notwithstanding the fact that the Denver water is difficult to purify. It is somewhat turbid and contaminated, but its worst feature is that it contains an extremely high content of micro-organisms of the worst variety. These organisms are short lived and their decomposition gives rise to tastes and odors extreme at some seasons of the year. A further difficulty is that some of the organisms in their live state are free swimming and have a remarkable tendency to penetrate and pass filters of the ordinary rapid type. They are so numerous that they would completely stop up slow filters.

SPECIAL FEATURES

The filter plant is one especially designed for this particular water and differs from the ordinary rapid filter plant in many particulars. Among the novel features are:

The low head losses used through the filters as well as the basins and conduits to make possible the use of the available head for adequate aeration

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[1] Consulting Engineer, New York, N. Y.

without pumping. The filters work under a maximum head loss of $3\frac{1}{2}$ feet instead of the customary 10 feet.

The use of coarse grained filters (0.7 mm. effective size, and uniformity coefficient of 1.8), with a 5-foot depth of filtering material.

The equipment of 5 m.g.d. filter units for operation by hand, rather than with rate controllers.

The use of large and extremely sensitive inspection wells for the observation of the filter effluents from each filter.

The novel gauges.

The use of closely spaced solid stream nozzles.

The use of fine screening preliminary to coagulation.

INTAKE AND FINE SCREENS

An intake of 90-inch concrete pipe extends into the lake 1300 feet to a depth of 60 feet and is equipped at the outer end with a removable conical brass screen with $\frac{1}{2}$-inch mesh. Double control gates are provided at the shore end. At this point also is a screen house containing forty and sixty mesh copper screens mounted on three motor driven belts, operating in a pit 57 feet deep. These screens are cleaned by sprays of water under 100 pounds pressure. The purpose of this installation is to remove the larger of the micro-organisms as well as any fish or debris which pass the coarse screen at the outer end of the intake. The screens take a part of the load from the filters.

AERATORS, MIXING CHAMBERS, AND COAGULATION BASIN

The water leaving the screens passes, by means of a 90-inch concrete pipe, through a Venturi meter to the aerators over the mixing chambers. The water enters the fifty independently valved, 10-inch cast iron lateral pipes and flows to six hundred bronze nozzles, spaced 3 feet center to center. The nozzles are of a type which throw the water up in a solid, straight stream. This method conserves of space, gains maximum height of stream and produces a large amount of entrapped air.

The water falls directly into the mixing chambers, at which point it receives the coagulants, the dosage varying from 0.2 to 1.0 grain per gallon of alum and 0.0 to 0.5 grain per gallon of lime. Although the raw water has a bicarbonate alkalinity of 100 p.p.m. and over, it is found that a small dosage of hydrated lime improves the coagulation. After passing through the five mixing chambers, having a total retention period of twenty minutes, and the coagulation basin,

FIG. 1. GENERAL VIEW OF MARSTON LAKE FILTER PLANT LOOKING NORTHEAST TOWARDS DENVER

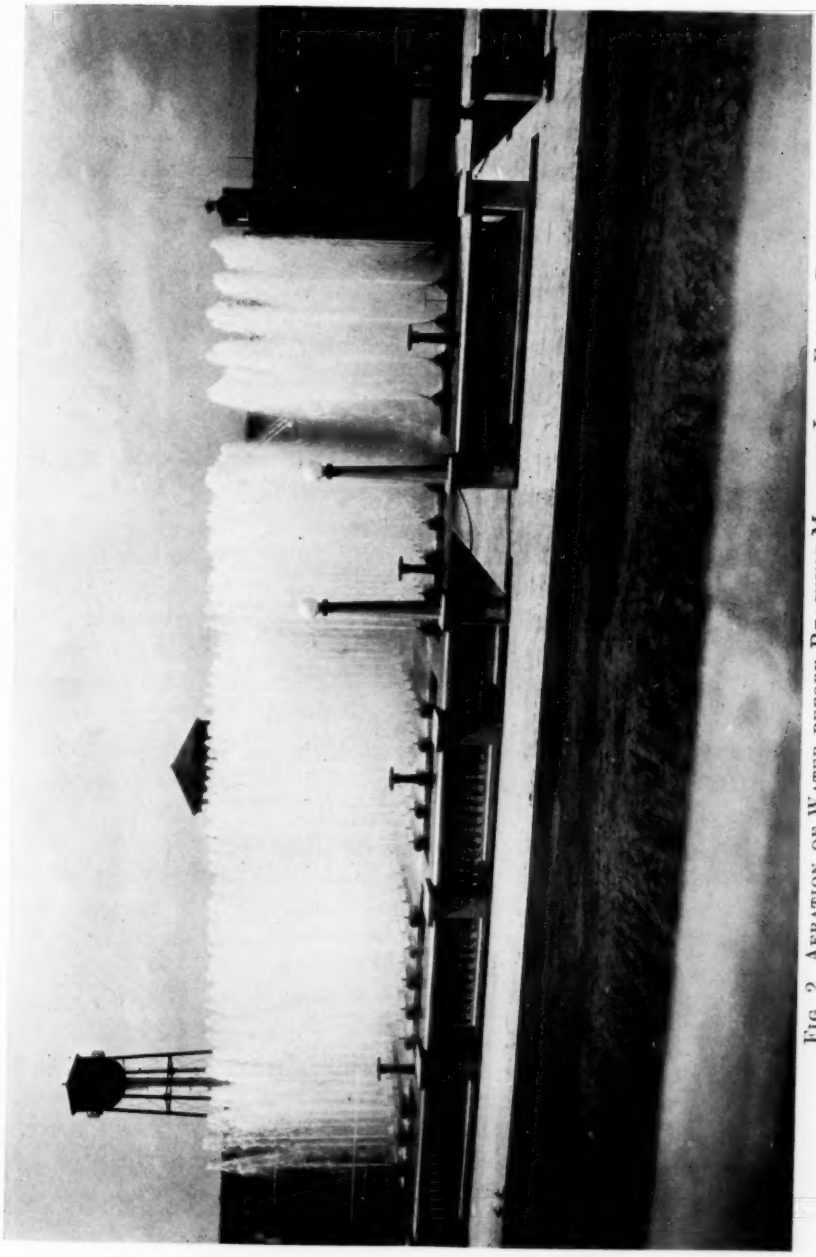

FIG. 2. AERATION OF WATER BEFORE REACHING MARSTON LAKE FILTER PLANT

the water flows directly to the filters, having had a total coagulation period of one hour.

In order to give an artistic design and at the same time provide an exposed water surface into which the spray from the nozzles will fall when blown by the wind, the coagulation basin is built surrounding the mixing chambers, the whole forming one large basin. This basin is provided with walks around and across it, so that the water may be observed during its coagulation.

LOW HEAD LOSS, HIGH RATE FILTERS

The coagulated water enters each filter from a flume at the end away from the central operating floor. All of the other filter connections are made to pipes and flumes in a pipe gallery under the operating floor.

The filtering material is hard anthracite coal, effective size 0.7 mm. and uniformity coefficient 1.8, placed in beds 5 feet deep and supported by 14 inches of gravel, graded in three layers and of a size varying from 0.75 to 0.05 inch. The strainer system is of 3-inch perforated pipes, 8 inches center to center with $\frac{3}{8}$-inch holes in their bottoms, 4 inches center to center, the same pipes being arranged to give a uniform distribution of both air and water wash. Reinforced concrete wash water gutters are used. Extremely sensitive inspection wells 7 feet deep are provided on the individual filter effluents. These have white glass bottoms which reflect light thrown from high-powered incandescent lamps above. The wells have transparent plate-glass covers.

The filters operate under a maximum head loss of $3\frac{1}{2}$ feet. They are controlled by hand without rate controllers, the water always being under close observance. The filters have both air and water wash, the latter varied in rate according to the character of the water treated, the usual operating range being 8 to 15 inches per minute.

All filters have rate of flow, loss of head and rate of wash gauges. The latter are actuated by loss of head of wash water and were calibrated in the field. The dials will be checked at intervals of time and, if necessary, corrected.

The filters are equipped with hydraulic valves, controlled from operating stands. The valves have attached directly to them position indicators, all visible from the operating stands.

The filter room is also provided with distant indicating gauges showing the level of the water in the clear water reservoir and the

FIG. 3. VIEW OF OPERATING FLOOR OF MARSTON LAKE FILTER PLANT SHOWING THE FOURTEEN 5-MILLION-GALLON UNITS

rate at which it is being drawn from the reservoir to the city. The rate of flow to the aerators and the water level in the coagulation basin is indicated at the head house from which point the inflowing water is controlled.

THE FILTERED WATER RESERVOIR

The reservoir has a capacity, when full, of 10 million gallons. This is covered by a flat slab reinforced concrete roof.

BOILER PUMP AND HEAD HOUSE

In this building is provided a storage room for two months' use of coagulants, this being above the room in which the dry feed machines are installed. Chemicals are stored on a flat floor. The tops of the hoppers of the dry feed machines are under hatchways in this floor and these hoppers are loaded once each shift when required. The mechanical equipment is in the same building and consists of:

Three 3500 g.p.m., 75-foot head, wash water pumps which pump water to a 160,000-gallon reinforced concrete wash water tank overhead.
One 500 g.p.m. 120-pounds pressure pump.
Two 250 g.p.m. 120 pounds pressure pump.
Two 300 cubic feet per minute 100 pounds air compressors.
Two heating boilers.

All mechanical equipment is electric driven, the power being brought in by two independent 13,000 volt lines and stepped down at an outdoor transformer sub-station at the plant.

GENERAL

Reinforced concrete is used as the structural material throughout. The housing is in buildings of light tan or brown color brick with red tile roofs. Construction work was started in June, 1924, and completed in July, 1925.

COSTS OF CONSTRUCTION

The entire plant of 64 m.g.d. capacity was built with an intake for $2,000,000, all costs except land, included. The cost of the filter plant alone amounted to $26,000 per million gallons daily.

As far as I know, this is one of the least expensive water purification plants for the treatment of a water as difficult to purify. This is notwithstanding the fact that certain local conditions of construction

made the work cost ten per cent more than might usually be expected. The usual cost for rapid filter plants at present prices, all costs included, is $30,000 to $40,000 per million gallons. Slow sand filter installations, operating at the usual rates, cost twice as much.

OPERATING COSTS

The costs of purifying water are the lowest of any plant that I know about, treating water under comparable conditions. The operation cost is $5.75 per million gallons. The total cost of purifying water, including interest, depreciation and all charges, is $9.75 per million gallons. This is based on the full rated capacity of the plant. Comparisons of operating costs with other plants are apt to be misleading, since costs vary so greatly with the character of the water treated, the size of the plant, local price conditions, and the wisdom and economy of administration. Some general comparisons of value may be made, however. I may say that the usual costs of purifying water under conditions at all comparable with those at Denver range from $11 to $18 per million gallons, all costs included, based on valuations at present prices, and with charges figured in a manner similar to that used for the Denver plant. I know of only one plant showing a cost as low as that at Denver. This is the plant at Montreal, Quebec, which was built after the findings of the double filtration plant at Steelton, Pennsylvania, mentioned herein.

Three particular items contribute to the economy at Denver:

1. Low labor cost. The plant is operated at the full rate by labor (total on payroll) of 2.0 man hours per million gallons.
2. Low doses of coagulants are used, the average for 1926 being: alum, 0.64 grain per gallon; lime, 0.27 grain per gallon.
3. Interest and depreciation charges based on the low installation cost given above, result in low fixed charges.

ADVANTAGE OF DENVER TYPE PLANT FOR USE IN CONJUNCTION WITH EXISTING SLOW FILTER

There are many existing slow filter plants which need increased capacity or will need it in the near future. The development of the rapid filters of the Denver type opens the way for the enlargement of these plants at a small installation cost and provides a means for the purification of the water at a cost lower than can be obtained in any other way. Their use as pre-filters enables these filters to operate at rates of from 12 to 15 as against the 2 to 6 million gallons

per acre per day now used. The purification effected by the double plant is of the highest character and offers a security furnished by no other method.

Reason for low construction cost of high rate double plant

The rapid filters work at a 50 per cent higher rate than is customary in rapid filter plant practice, or that usually used in prefilters. This means 50 per cent less filter area. The preliminary filters of the type in question are simpler of operation and require less regulating and control apparatus than the usual mechanical filters. The slow filters working at rates three to five times as great as those usually used result in a small filter area and a low installation cost. Where existing slow filters are now in good condition, they can be adapted for use at high rates with a double plant by minor changes of piping and regulating apparatus and by a re-sizing of the sand. As compared to an abandonment of present slow filters, or a continuance of their operation as at present, supplemented by filters of another or of the same type, the double plant as above considered gives by far the lowest installation cost.

Reason for low operating cost

First, the double plant of the type considered will use extremely low doses of alum. An example of this economy is offered by the comparison of the Harrisburg and Steelton plants in Pennsylvania, both treating Susquehanna River water. The Steelton plant in addition gets Harrisburg's sewage. The plant at Harrisburg is a rapid filter plant of a type quite similar to many now in use. The Steelton plant is a double filter plant of the type under discussion here. The Steelton plant operates on an average dose of 0.18 grain per gallon of alum, whereas Harrisburg uses 0.5 grain per gallon. Seven tenths to one grain is perhaps more usually experienced for similar waters. The saving here is one dollar per million gallons. Secondly, because of the low installation cost, the fixed charges will be correspondingly low.

I have recently made estimates for the enlargement of two rapid sand filter plants by the addition of preliminary high rate scrubbers and the increasing of the rate on the slow filters. They have exemplified to a marked degree the economy of the method. In preparation for one of these changes for a plant enlarged to 50 m.g.d.

capacity test filters have been operated for almost a year and estimate designs prepared. It was found that the double filter plant would make a saving of several hundred thousand dollars in first cost over any other type of enlargement, and would net a saving in costs of purifying the water of $15,000 per year. The other plant is a similar case, though slightly smaller, and it was found that the saving by the use of double filters of the above mentioned type would be over $100,000 in construction cost and between $10,000 and $20,000 per year in operating costs. In both cases it was found that the water would be purified by the double plant at a cost considerably under ten dollars per million gallons delivered, all costs included, with complete plant valued at present prices.

The fact that operating costs as low as those contemplated can be actually accomplished has not only been demonstrated by the experimental station at Denver and at Harrisburg (these were actual plants on a small scale), but also by the operation of the 3 m.g.d. plant at Steelton, Pa. This plant has been in operation for nineteen years and, although a small plant, data from it are applicable in the establishment of costs of operation for a larger plant. Furthermore, the 64 m.g. plant recently built at Denver, which has been in operation or a year, further corroborates the figures. This is a rapid plant only, but it is of the same type which is considered in this paper for use as preliminary filters for a double plant.

An added advantage of double filters is in their extreme reliability. One of the greatest weaknesses of any plant for the purification of the public water supply is in the possibility of human failure. If everyone is on the job all the time and if everything is working as it should be, the plant will work all right, but these things do not always happen. Someone forgets and somebody is not there, or some part of the operation or equipment is out of order and, consequently, some water gets by not properly purified. In recent years the application of chlorine has furnished a great safeguard of reliability, but chlorine machines, like other mechanical equipment, are subject to periods of break-down or to being shut off when no one is looking, to save a few dollars.

Too much emphasis cannot be placed upon the necessity of absolute reliability. Double filters offer a reliability which is perhaps furnished by no other means. If for some reason the pre-filters are out of service or do not stop the contamination it is sure to be caught on

the final filters and the chlorine offers a further protection which it is well to have.

These facts of reliability are not new ones. They have been appreciated for years and probably more in Europe than in this country. The reason that double filters have not been more used in the past is that they have been more costly to build and operate than other types of purification plants. Now, however, with the fact established, as I believe it has been by the work above mentioned, that double filters can operate at rates so high and doses of coagulants so low that the costs of purifying water are actually below those usually obtained, the double filter plant seems very attractive.

DISCUSSION

FREDERICK H. WEED:[2] Mr. Fuertes' paper describes a water filtration plant which is strikingly different from the usual practice. For this reason and because of the unusual character of the water treated, the plant is worthy of note by water works' men. The latter part of the paper, which deals with the applicability of filters of the Denver type for use as scrubbers of a double filter plant, and the consideration of the use of high rates on such a plant is in a field which, I believe, will be found new to many men. There are others, however, who have had experiences along this line and it is hoped that this paper will bring out many discussions. There are many cases where the use of high rate double filtration will give better results than either mechanical or slow filters alone, at no greater cost and with a greater certainty of safety. Where there are existing slow sand filters, the opportunity of an economical development by this means is great.

Since the writer carried on certain parts of the work mentioned in Mr. Fuertes' paper, it may be to advantage to set down some of the details not included in his general statements. The work in Denver did much to confirm the earlier results obtained from the double filtration plant at Steelton which was put into operation in 1908 and those of the experimental plant operated at Harrisburg prior to the construction of the rapid filters for that city.

[2] Formerly with James H. Fuertes, Consulting Engineer, New York, N. Y., now with Gannett, Seelye and Fleming, Engrs., Inc., Harrisburg, Pa.

A YEAR'S TEST FOR A DOUBLE FILTRATION PLANT FOR DENVER

In preparation for the enlargement of the old slow filter plant at the foot of the Platte Canyon at Denver, an experimental filter plant was operated for a year to test the effect of high rate double filtration. These tests were made with a small filter plant made for the purpose. This had a maximum capacity of 180,000 gallons per day. This plant showed to a marked degree the applicability of the high rates considered by Mr. Fuertes for use in a double filter plant. The water treated was contaminated and, at times, carried a high turbidity. Judging from the results obtained by this plant, the high rates as considered by Mr. Fuertes are not excessive. The rapid filters operated for days at a time at rates up to 220 m.g. per acre per day, handling water of over 100 p.p.m. turbidity with maximum turbidities up to 600 p.p.m. The average rate over the whole period in which the worst water was treated and covering the wide range of rates tried was 160 m.g. per acre per day. The effluent from these rapid filters which was put on to the slow filters averaged a turbidity of 2 p.p.m., which was completely removed by the slow filters, as far as the usual turbidity tests would indicate. The slow filters operated at an average rate of 18 m.g. per acre per day, which included the wide fluctuation of rates tried. The filters showed a capability of treating this water up to rates of 23 million gallons per acre per day. Furthermore, the slow filters, under these conditions, delivered 500 million gallons of water per acre cleaned. At no time was the effluent of the plant other than first quality for a municipal supply.

Bacterial efficiency of the plant

Bacterial efficiencies were measured without the use of chlorine or any disinfecting agent. The plant showed an average bacterial efficiency at the rates considered safe by Mr. Fuertes (15 m.g.a.d. on slow filters, 175 m.g.a.d. on scrubbers) of 98 per cent. This efficiency is about what might be expected from a slow filter plant alone operated at a rate of approximately 6 m.g.a.d., and is considerably better than that obtained by the usual rapid filter plant, working at 100 to 125 m.g.a.d. which, if I am not mistaken, might show efficiencies without the use of chlorine of from 80 to 90 per cent on waters somewhat similar to that treated at Denver. It is recognized, of

course, that a greater bacterial reduction can be secured by an increased dose of alum applied for this particular purpose.

The efficiency of the slow filters alone of this test plant is worthy of note. There have been some cases put on record where the efficiency of slow filters varied inversely as the square of the rate of filtration. With this plant, however, the indication was that the efficiency dropped much less rapidly with the increase of the rate, in fact, more nearly in direct proportion to the increase of rate rather than its square. The average efficiency of the slow filters at 15 m.g.a.d. was 95 per cent.

THE STEELTON FILTERS

Mr. Fuertes mentioned the double filtration plant at Steelton as an example of high rate double filtration. While the matter is under consideration here, it may be well to state that this plant treats the Susquehanna River water which has an average turbidity of 50 p.p.m. throughout the year and a maximum turbidity running for days at a time of 1500 p.p.m. The pollution by sewage and mine wastes is high. This plant operates throughout the year with an average dose of alum of less than 0.2 grain per gallon. The coarse grained scrubbers remove nearly all the turbidity, the final filters taking out the rest and effecting the principal bacterial purification. Notwithstanding the low alum doses, the final filters give long runs and have shown no sub-surface clogging in their nineteen years of operation. The filters deliver approximately 350 million gallons of water per acre cleaned and at times have gone to 500. Throughout one year they delivered 1700 million gallons per acre cleaned. With as little cleaning required as this, it can be readily seen that the costs of the slow filter operation are very low. The rates of filtration at Steelton are not nearly as high as those considered at Denver and Montreal.

MONTREAL FILTERS

In regard to the Montreal filters, mentioned by Mr. Fuertes in his statements about double filtration, it may be said that as far as the writer knows this plant has the largest high rate double filtration plant in operation. It delivers approximately 75 m.g.d. and operates with the rapid filters working at average rates of 175 m.g.a.d. and the slow filters at 11 to 13 m.g.a.d. This plant gives an extremely low cost of purifying the water. Although the water at

Montreal is not as difficult to treat as that of the Susquehanna River at Harrisburg and Steelton, or the Denver water, it may, nevertheless, be of interest to make a comparison of costs. The average turbidity runs about 11 p.p.m. with maximums of 100 or 150 p.p.m. The water is contaminated.

According to the paper by F. E. Field, in the Journal of the New England Water Works Association, Vol. 39, No. 3, the cost of operation for 1924 was $2.50 per million gallons. Probably the total charges based on present valuations and figured on the same basis used by Mr. Fuertes would give a total cost of purifying the water of about $8.50 per m.g. The slow filters give high runs per cleaning of approximately 375 m.g. of water per acre cleaned.

It has been stated that the double filter plant at Montreal was built to protect the slow filters from plankton growths and that, since the growths have not occurred to the extent anticipated, the double filters are not justified. I understand also that in the enlargement which is to be made at Montreal, rapid filters only are to be built. These facts are, however, not a detriment to the citing of Montreal as evidence of the economy of double filter plants, working at high rates, as demonstrated by Mr. Fuertes in his work, since this plant has been in operation for eight years, giving excellent results at extremely low costs. In fact, the Montreal experience may be the most conclusive proof to those who like to see proof on a large scale and who would give some discredit to results obtained by a test filter plant, and would perhaps consider the three million gallon plant at Steelton a small scale demonstration only. Without doubt, if there were any slow filters now working at low rates at Montreal, it would be better to increase their rate with pre-filters rather than build supplementary mechanical filters. The only slow filters they have already operate at the high rates.

ADVANTAGE OF LOW HEAD SCRUBBERS

There are many cases where the low head feature of the scrubbers, as developed by Mr. Fuertes is very valuable. When pumping can be avoided a considerable amount of money is saved. The necessity of pumping the water through a filter plant often increases the cost of purification by 25 per cent.

SUMMARY

The real advantage, as the writer sees it, in the type of double filters as developed by Mr. Fuertes, is that his plant utilizes to the best possible advantage the qualities of both slow and rapid filters. The scrubbers treat the water only to the extent required for the most economical operation of the slow filters, and no more. The amount of coagulation and alum required will vary from nothing, as at Montreal, to some extent, such as used at Steelton, but in all cases will be much less than would be required by the usual mechanical plant. The combined plant, so arranged, can operate at such high rates that the costs (including fixed charges) of purifying water are as low as can be obtained by any method, and lower when there are existing slow filters to be enlarged. This, of course, can not be made as a general statement applying to all waters, but the fact is so well demonstrated on the waters for which the plants have been tried that it seems reasonable to suppose that there may be as decided an advantage on the other waters also.

As to whether the advantage exists for any particular water can be easily demonstrated by a test plant at small cost which may pay for itself a thousand times over. Where there are existing slow filters working at the usual rates of filtration, the double filtration plants operating at high rates seem extremely attractive for further extension.

The new 64 m.g.d. water purification plant at Marston Lake, Denver, of which the writer was in charge, representing Mr. Fuertes during the design, construction and early operation, has now been in use for eighteen months. Its record justifies the conclusions drawn from it and applied to similar filters used as scrubbers of a double filter plant.

CROSS CONNECTION POLICIES[1]

By Arthur E. Gorman[2]

The cross connection problem has been, during the last decade, a perennial affair in the water works field. To some who consider an issue closed with the enactment of prohibitory regulations and the establishment of administrative policies, further discussion of cross connections is repetition. Be this true or not the fact remains that the cross connection problem is still and probably always will be one with which the efficient and wide awake water works official must cope.

In its ramifications cross connection work affects many factors in our modern civilization. The health officer is primarily concerned, as the existence of cross connections jeopardizes the public health; industry is affected, as it must have assurance of a continuous and abundant water supply for its numerous processes, and the fire insurance companies assert their rights for adequate protection of the property for which they are responsible. Each group very properly asserts its rights and maintains its claims before the ever obliging water works official, who finds himself in a serious quandary.

The health officer with his broad police powers and public sympathy can prosecute a sweeping campaign against cross connections of all kinds and types; the industrial plant manager driven to distraction can usually find a political friend or two to support his case, while the fire insurance companies can always play their trump card of increased rates. With these human complications it is a wise water works official who analyzes the entire situation in a broad way and then applies certain basic principles to conditions in his own city or town and works out the rest as his common sense and conscience dictates. By this plan he may not, and probably will not, fully satisfy all concerned. The health officer may not attain a 100 per cent removal of cross connections at once; the industrial plant manager may be temporarily inconvenienced, and the fire insurance

[1] Presented before the Indiana Section meeting, February 18, 1927.

[2] Chief Sanitary Engineer, Division of Water Safety Control, Bureau of Engineering, Department of Public Works, Chicago, Ill.

official may be compromised on his increased rate decision, but the chief object—a harmonious and intelligent study of the problem, with all eyes on the same plane—will be gained. And it is fairly safe to say that in a few years the problem will be largely solved, with the water official and his company the greatest benefactor from the whole issue.

During 1924 and 1925, while the writer served as Chief Sanitary Engineer with the Chicago Department of Health, we conducted an extensive cross connection campaign, during the course of which nearly 500 illegal connections with the city water supply system were found and a wide diversity of situations was encountered. The unusual success which marked our efforts is considered almost wholly due to the strict adherence to the firm but "man to man" policies delineated by Health Commissioner Herman N. Bundesen.

While the plan for the initial surveys was being worked up one of our first thoughts was to draft a drastic cross connection ordinance with severe penalties for violations. The original of this ordinance is still in the files and as yet, outside of a regulation in the book of rules of the Division of Water Pipe Extension in the Bureau of Engineering, Department of Public Works, no legal crutch has become necessary. Generally speaking, the plan pursued was to assign inspectors to visit every plant adjacent to the Chicago and Calumet rivers and their tributaries, as well as along the lake front and other water ways. Cross connections found were brought to the attention of the engineer or plant attendant on duty and if he had sufficient authority to do so, and was so inclined, the connection was broken then and there and a final report returned and duly filed. Otherwise a letter was written direct to the managing official concerned and the potential danger of maintaining the cross connection explained, with a request for prompt authorization of its removal. In most cases where the cross connection was a minor one a favorable reply was received advising of compliance with our request. This called for a reinspection and a final "out" report. Where delays in answers or excuses developed, a personal call was made on the official of highest authority who could be reached. A very satisfactory percentage of favorable actions resulted from this policy. If the official interviewed did not possess sufficient authority to incur the expenditure necessary, this personal call usually "sold" him on the proposition or gave him sufficient first hand information to make a complete report to his superiors with favorable recommendations.

In dealing with large corporations, such as the railroads and the packing companies, it must be borne in mind that the operating and plant managing officials must receive special authority for expenditures not included in their regular budgets. In this connection a reasonable amount of patience with these officials will usually be well rewarded. Persistence and firmness are always virtues in directing a cross connection campaign and must be tactfully made evident when unusual delays develop. In some of our cross connection work in the Union Stock Yards we worked over a year before final separation of dual water systems was completed, but in the meantime a cooperative plan for disinfecting the inferior supply was worked out. Reinspections at reasonable intervals, say at least quarterly, are important in impressing the importance of the work and for effective control.

A complication common at plants where dual water supplies exist is the cross connection made by repair or remodeling contractors unfamiliar with the various piping systems. In many large institutions there is a maze of piping and when two water systems exist, even with extreme care, dangerous cross connections may be made in ignorance. Cases of this kind may easily occur where multiple piping passes through or around partitions with sharp and irregular changes in direction and pipe sizes. At some of the large packing plants in the Union Stock Yards where two and even three sources of water are used, and repairing and remodeling were almost always in progress, this complex was met by identifying the various piping systems by painting them different colors. While complete painting of all lines is preferable it is expensive and not necessary. The vital points which need identification are the branches, either side of partitions, and pump suctions and discharges.

In long pipe sections the junction points can be painted. Where pipes are covered, painting is easy and satisfactory. Uncovered pipes offer some difficulties, such as "sweating" due to condensate and peeling of the paint. In these cases sheet steel bands or flags can be attached around or suspended from the pipe. The pipe identification practice has been followed out successfully on Great Lakes' passenger vessels for four years and is being used in many of the most modern power plants in this country. As fire lines are usually painted bright red, the writer has suggested light blue as symbolic of pure or first quality city water, with yellow as re-used city water.

While the size of a cross connection has a real bearing on its im-

portance, the degree of contamination of the inferior supply should be the basic criterion in determining the policy for its removal. It may happen that an inspector will recommend vigorous and immediate action for the removal of a 12-inch cross connection with a secondary supply of city water collected in a well protected reservoir, but overlooks a 2-inch direct cross connection with a sprinkler system through which grossly polluted river water is pumped. Obviously, the public health value of cross connection work depends on an early and complete separation of all cross connections with dangerous sources for water. In expediting this work there can be no safe compromise with double valves, etc.

Common sense is certain to be at a premium in this work. In the case of the 12-inch and 2-inch connections just mentioned it may be that the secondary source of supply is absolutely necessary for safe plant operation and the public health risk in the cross connection a mild one at best. In such a case would it not be better to be liberal with the plant management and permit, subject to supervision, for a reasonable period this 12-inch cross connection and obtain a prompt removal of the dangerous 2-inch connection?

The use of sterilizing agents such as chlorine properly controlled and supervised has, I believe, a real application in the granting of temporary cross connection permits, pending the development of an improved system. In many instances industry has suffered due to a rigid enforcement of cross connection ordinances where relief was beyond its control. For instance, when the public water service is inadequate for the industry's purpose a real problem confronts the water works official and the health officer if a satisfactory solution of the cross connection situation is to be made. Where a first class public water service is available industry is usually open to any reasonable proposition which involves the public health. If not the health officer has a clear case in his favor and cannot fail in enforcing his proper police powers.

In summarizing, the recipe I offer you for a successful cross-connection based on our Chicago experience is, first, find out the true facts; add a goodly amount of common sense seasoned by a thorough understanding of local conditions and balanced by a real appreciation of the public health values involved, after which make a direct and human appeal to the parties concerned, following up all this with an attitude of patience, persistence, firmness and fair play.

CORROSION IN A WATER SUPPLY SYSTEM AND METHODS OF PROTECTION[1]

By E. B. Stewart[2]

The subject of corrosion has not been given the consideration in the past which its importance might warrant. The lack of interest is probably due to the fact that pipe systems are, as a general rule, looked upon as practically indestructible, and when once installed require no further attention or replacement. Experience has shown, however, that pipes are always subject to corrosion and, under certain conditions, serious damage occurs in a short period of time.

Many corrosion problems have simply been looked upon as unavoidable and repairs and replacements have been made without any effort to locate and remove the cause.

The subject of electrolysis will always be pertinent so long as the running rails are used as a return path for the railway current. Improvements in rail bonding, the use of larger rails, and the more frequent distribution of substations, thereby reducing the distance that return current must travel on the rails, have been of material aid in reducing this form of corrosion.

THEORY OF CORROSION

Before taking up methods of preventing corrosion, a brief explanation will be given of the manner in which corrosion takes place, for unless there is a fair conception of the fundamental factors influencing corrosion rates, it will be difficult to know what protective methods will be most suitable.

It has been conclusively shown that corrosion does not take place to any appreciable degree unless the metal be in contact with both water and free oxygen. The action is practically nil where the metal is in contact with oxygen alone, or oxygen-free water alone. In other words, all three elements, namely, metal, water and free oxygen, must be brought in contact to cause corrosion.

[1] Presented before the California Section meeting, October 29, 1926.

[2] Electrolysis Engineer, East Bay Water Company, Oakland, California.

When iron is placed in water, a multitude of electric potentials are immediately established between the metal ions and the electrically charged ions in the water. These potentials cause metal ions to go into the solution and set hydrogen free. This hydrogen gathers on the surface of the iron in the form of a thin invisible film and tends to retard the progress of corrosion by insulating the metal from the solution, and thus prevents further corrosion taking place. In order that corrosion may continue, the film of hydrogen must be removed. This may be accomplished by dissolved oxygen which is usually present in water combining with the hydrogen film to form water. The film having been removed, more iron can go into solution, more hydrogen can plate out and the process can continue at a rate determined by the speed with which the oxygen removes the hydrogen.

The tendency of a metal to go into solution in a conducting liquid called the electrolyte is accompanied by an electrical potential between the metal and the solution. This potential is known as its "solution pressure" or "potential pressure" and is different for different metals in contact with the same solution and also different for different solutions in contact with the same metal.

Hence when two dissimilar metals are placed in a conducting liquid, a galvanic battery is formed and the difference in potential between the metals is proportional to the difference in their "potential pressures." When the metals are connected by a wire, an electric current will flow through the wire between the metals, and the electropositive metal will corrode at a rate inversely proportional to the resistance of the circuit. Therefore, the rate of corrosion will be a maximum when the metals are brought in physical contact, which is usually the case in practice. In this case the circuit will be completed internally through the metals.

Corrosion resulting from contact of dissimilar metals is commonly called "galvanic action." This form of corrosion is often not generally understood, probably because it occurs under conditions difficult to study.

An example illustrating the effect of corrosion from this cause in practice is found in the destruction of our service pipes at the union connecting the lead goose neck. Many cases have been found where the service pipe shows general corrosion immediately adjacent to the union. The service pipe is the electropositive metal, hence a galvanic current will flow from the pipe to the union, resulting in corrosion of the former.

An insulating bushing placed between the pipe and the union was found to be the most economical method of preventing this type of galvanic corrosion. The electrical circuit is thus broken and the corrosion hazard is eliminated. This insulating medium also prevents the flow of stray railway currents.

There are many cases where it is impracticable to insulate dissimilar metals from physical contact with each other, particularly in well pumping equipment. In this case, it is desirable to select materials that are most uniform in texture. In some cases where cost is an important factor and the extent of the corrosion is limited, it may be advisable to select such combinations of metals as to make the least expensive metal electropositive and the most expensive electronegative.

SOIL CORROSION

Natural soil corrosion is sometimes spoken of as "self corrosion" to distinguish it from corrosion due to externally applied electric currents.

On the whole, corrosion in soils is similar to corrosion in water, because the controlling factor in soil corrosion is water. For in the absence of water, no corrosion will take place. But since pure water does not corrode iron appreciably, it is obvious that the corrosive character of the soil depends primarily upon the presence of certain dissolved materials in the soil water, which originate both from the air and from the ground. In other words the soil is an electrolyte of widely varying concentrations due to the many factors present such as soluble salts, acids, dissolved gases, etc., which make a solution of high electrical conductivity and hence more stimulating to corrosion than pure water.

There are certain physical properties of pipes which have more or less influence on the corrosion rate, such as character and uniformity of the surface finish of the metal, segregation of impurities in the metal, composition of the metal, area of the metal exposed as anode, parts of the metal that have been scratched or bruised from rolling, hammering or threading. Some of these factors influence the total amount of corrosion. For instance imperfections in mill scale will cause pitting which is the most destructive form of corrosion. Mill scale is electronegative to iron, and hence galvanic action takes place between them when in contact with a conducting solution.

It is obvious that differences of potential exist between points on

the pipe surface that are in contact with soils of different concentration, since it is known that the "potential pressure" of a metal is different for different solutions. It follows, therefore, that galvanic currents will flow through the pipe between different points of concentration on the pipe surface, entering the pipe at points of low concentration and leaving the pipe at points of high concentration, causing corrosion at points where current leaves the pipe. That corrosion does occur in accordance with these conditions has been verified by the writer by placing non-polarized electrodes about six inches apart at right angles to a steel pipe and noting the difference of potential between them when one electrode is very close to the pipe. Two points were located three feet apart where current was flowing away from the pipe at one point and entering the pipe at the other. An examination of the pipe indicated that corrosion was in progress at the point where current was leaving the pipe, while the pipe was found in good condition where current was entering.

This brings out the fact that corrosion is stimulated when parallel mains are laid in close association with each other for the pipes act as conductors to complete a galvanic circuit between points of different concentrations in the soil. To illustrate the effect of corrosion under these conditions, a steel pipe laid eighteen inches distant from a parallel sixteen-inch main that was abandoned, showed with an earth current meter a relatively large galvanic current leaving the pipe toward the abandoned pipe at a point where serious corrosion was in progress. When the abandoned pipe was removed, this point became negative to the earth, thus preventing further corrosion. We have found from earth current measurements that pipes laid parallel in the soil should be at least four feet apart in order to prevent the flow of destructive galvanic currents.

One of the outstanding problems that confronts water works people, together with all other utilities owning underground pipes, is the development of improved means whereby the corrosive power of certain soils may be determined. If it were possible to determine the corrosive power of the soil, it would be possible to determine what form of protection, if any, would be most suitable for a particular kind of pipe at a minimum cost. The present knowledge of the corrosiveness of any particular soil is based largely on practical experience of the corrosion of pipes in similar soils.

In 1922 the American Committee on Electrolysis and the National Bureau of Standards in coöperation with a number of pipe manu-

facturers buried thousands of small samples of different kinds of pipe in about forty locations widely distributed throughout the entire country, to obtain a further knowledge of the effects of different kinds of soil on the corrosion of buried pipes. All kinds of soil and climatic conditions have been included in the tests. It is the plan to submit tentative reports as fairly definite results develop. The whole investigation is being carried out by the Bureau of Standards and is being watched with great interest by the manufacturers and users of pipe.

Our investigations of the corrosiveness of soils indicate that very little corrosion occurs in soils having a resistance over 1000 ohms per cubic centimeter.

PREVENTIVE MEASURES FOR SOIL CORROSION

Damage to pipes by soil corrosion may be prevented by two methods: (1) Covering the pipe surfaces to insulate them from the earth. (2) Making pipes negative to earth by external current or by the application of more anodic metals. This method is known as cathodic protection.

In the study of soils to determine the type of coating necessary to prevent soil corrosion, stray current from railway tracks should be taken into consideration. For instance, no coating is necessary on pipes located on railway lines where the potential of the pipes is negative to the rails regardless of the kind of soil, because it is well known that no corrosion takes place where pipes are negative to the earth. In some cases we have made small pipes negative to earth by connecting zinc plates to the pipe at intervals determined by earth current measurements. The plates are buried in the soil approximately one foot from the pipe. Insufficient data are available at present to determine the probable life of such protection, but, from all indications, it appears to have some merit as a temporary expedient in localized cases.

ELECTROLYSIS

Corrosion from stray current is of special importance in cities where buried metallic conductors come in more or less close association with electric railway systems. The chief factors involved in dealing with stray current electrolysis comprise the testing for, and the control of, stray currents responsible for the damage.

The majority of the street railways of the country are operated on the single trolley system using the rails to return the current back to the power station. The total current, however, will not return to the power station by the rails; a part of the current will shunt from the rails to earth in the negative area and find its way to nearby networks of metallic underground structures and flow on them in a general direction toward the substation. As the station is approached, the current tends to leave the structures to earth and return to the rails. Corrosion will take place where these currents leave the pipes to earth.

Experience has shown that stray currents also leave the pipe in the negative zone at remote distances from the ends of the car lines, a condition which is somewhat contrary to the usual explanation of the flow of stray currents. This condition is made possible by two separate tracks leading from the same power house and laid out in such a way that the return of one line is almost without loss of potential, while the other has considerable loss. In this case part of the current will leak across through the earth to the track which is without loss of potential. These currents will accumulate on the pipes running in the same general direction and very often cause rapid corrosion.

An example of corrosion from stray current in accordance with these conditions was found at a point one mile distant from the end of the nearest railway line. Earth current measurements showed an average current of six milliamperes leaking to earth from every square foot of pipe. This is an unusually high leakage current, when it is considered that leakage values below 0.5 of a milliampere per square foot are considered safe.

MEASURES TENDING BOTH TO RAILWAY ECONOMY AND THE REDUCTION OF STRAY CURRENT

The magnitude of stray currents is determined by the design, construction, maintenance and operation of the railway system. In the effort to eliminate the corrosion from stray railway current, the most logical procedure is to attack the trouble at its source, the production of the stray currents.

An analysis of the power distribution and the operation of the railway is the most essential factor to consider when making electrolysis surveys.

The question of electrolysis has been very actively studied for a number of years by the "American Committee on Electrolysis"

which was formed from representatives of the various public utility associations whose interests were affected. Most members of this Association are probably familiar with the report of the Committee issued in 1921.[3] This report represents the unanimous opinion of the representatives of all the different interests involved.

A matter of particular concern is the study and development of railway distribution. Considerable progress has been made in recent years in the development of automatic, semiautomatic and remote control substations, and these are now being used on both city and interurban lines. The economic operation of such substations makes possible a greater number of feeding points than can economically be supplied through manually operated stations. The increase in the number of substations will obviously reduce the feeding distances, and effect a saving in distribution copper and in line and return losses. The general effect is the reduction of track voltage drops; thereby reducing the leakage of stray current into the earth.

This is a very important development in railway operation for the protection of damage to pipes from electrolysis, as the same factors that determine economy of railway operation also control the leakage of stray currents to earth.

Within the last year, four additional substations have been added to the local railway system within the territory affecting our piping system and recent surveys show that such measures have materially reduced stray currents in the piping systems.

REMEDIAL MEASURES APPLICABLE TO AFFECTED STRUCTURES

The principal measures used by this Company to eliminate or reduce corrosion from stray current are: (1) Electrical drainage; (2) insulating joints; (3) electrical connections between pipes in close association.

Electrical drainage

Electrical drainage is used to drain enough current to make the pipes negative to the earth in the vicinity of negative feeder connections. While electrical drainage is not considered good practice by many engineers, nevertheless, under certain conditions, it appears to be the best temporary expedient consistent with economy. Where large mains are already in place, it seems logical to apply a limited

[3] Summarized in the Manual of Water Works Practice.

amount of drainage until such time as remedial measures can be applied to the railway system. Electrical drainage is applied in coöperation with other utilities through committee activities which will be discussed later in this paper.

Where drainage systems are in use, very careful surveys and inspections must be made at frequent intervals, if adequate protection is to be realized, as changes and extensions to either railway or underground systems will establish added points of hazard.

Care must be taken to avoid unequal drainage between pipes that are in close association. The drainage of one system of pipes will, of course, lower its potential with respect to the neighboring pipes tending to injure the latter. This in turn calls for drainage of the injured system which may in turn damage the first or other structures and consequently a system of competitive drainage is established.

Overdrainage of cable systems is very often a hazard to pipe structures. Pipes as a rule are much closer to cable conduits in the ground than they are to rails. In many cases, the pipes are resting directly against the conduit. Under such conditions where both metals are in wet soil, it is possible for large leakage currents to flow and cause damage to the main or service pipe. In one particular instance, overdrainage of cable systems caused serious damage to one of our transmission mains on a street where no electric railway tracks exist. This condition brings out the fact that potential measurements between pipes and cables should not as a rule be confined to streets having railway tracks.

Insulating joints

Insulating joints are used in new pipe lines and some existing lines in negative and neutral zones with particular reference to those points where it is expected that large transverse currents are flowing between parallel rails due to unusually high voltage drops between them, or where it is expected that currents will be transmitted to and discharged from the pipes in soils of low electrical resistance. In the insulated sections, the service pipes are prevented from making electrical contact with other piping systems by the use of insulating joints at the meters. Without insulating joints in the service pipe, stray current could enter from the other piping systems through gas water heaters and other appliances with which it comes in contact and injury would result to both the service and the section of the main to which it connects. It is often necessary to install insulating joints on

cross mains which connect the insulated sections. We have found from laboratory studies, together with studies in the field under working conditions, that cement used as an insulating medium offers the highest electrical resistance to the flow of stray current, and when joints are placed at regular intervals of approximately 100 feet, the current flow on the pipe lines is reduced to relatively small values. Resistance measurements of a number of insulating joints that were in service for approximately three years, showed an average electrical resistance of 0.6 ohms in soils having a resistance below 1000 ohms per cubic centimeter. In many cases the resistance of an insulating joint is greater than the resistance of 400,000 feet of pipe.

The principal objection that has been raised to the use of insulating joints is that corrosion is apt to occur on the positive side of the joint. During the last four years we have engaged in regular tests and inspections for joint corrosion and to date no corrosion from this cause has been located. Such installations might fail to protect the pipes in many instances because of the too infrequent use of insulating joints, especially if the pipe line is laid parallel with high potential gradients in the earth.

For example, in a case, where the difference of potential in the earth is, say, ten volts per 1000 feet, and a pipe line is located in a direction approximately parallel to the electromotive force, heavy currents will, as a rule, be picked up by the pipe, and if this is discharged into the earth, serious damage will, of course, result. If the continuity of the pipe is broken up by inserting insulating joints, then practically all of the potential drop would be concentrated at the joints. For instance, if two insulating joints are inserted in a pipe 1000 feet in length, the drop across each joint will be approximately five volts.

Since the leakage path around such joints is usually very short, it is evident that high voltage potentials will produce a correspondingly high current density across this short distance in soils of low electrical resistance, and, as a consequence, sufficient currents will flow around the joints to destroy them within a comparatively short time. It is evident that in order to prevent this, a sufficient number of insulating joints must be used so as to reduce the current density around the joints to a practical minimum. In other words, the frequency that insulating joints may be placed to secure adequate protection against electrolysis is determined by two factors, namely, potential gradients in the earth and electrical resistance of the soil.

To illustrate a practical example of the effectiveness of insulating joints, a sixteen-inch non-insulated steel pipe having been destroyed beyond repairs after less than three years' service was renewed with the same size and kind of pipe with insulating joints placed at regular intervals of 100 feet. This pipe has been in service a little more than four years, and to date, it has not suffered damage from electrolysis, although subjected to the same stray current conditions.

Earth current meter

The most difficult part of an electrolysis survey, perhaps, consists in drawing proper conclusions. No one set of measurements will suffice as a basis. While potential measurements represent the tendency to produce stray currents, the currents which cause the damage are determined as well by the resistivity of the soil, which varies over wide limits from one part of the city to another. Currents flowing in the pipes will be affected by the relative location of the pipes and the rails in the streets. Services or mains passing very close to the rails will have large stray currents, and these currents are likely to leave over restricted areas, causing more concentrated corrosion. The current strength in pipes cannot always be used as an index of electrolysis hazards. Relatively large currents may be flowing on a pipe without causing any corresponding damage for these currents do not flow to the soil. On the other hand, relatively small currents may be flowing along the main and yet corrosion may be taking place.

Heretofore our greatest difficulty encountered in electrolysis testing has been our inability to measure directly the factor responsible for the corrosion, namely, the density of the current flowing from a pipe to earth. It was evident, therefore, that there was a need for improved means of electrolysis testing, whereby it would be possible to determine the polarity of the pipe with respect to earth, and for the quantitative measurement of current density at any desired point in the earth.

An earth current meter was developed by Burton McCollum of the United States Bureau of Standards and was described in some detail in The Electric Railway Journal of November 21, 1921. This instrument enables one to determine the actual density of current discharge from the pipe which is measured in terms of milliamperes per square foot of pipe surface. We have used this instrument for electrolysis testing for the past two years and have found it to be well

adapted for use under practical conditions. By the use of this instrument, information can be had showing far more definitely the actual electrolysis conditions prevailing on any particular point than it is possible to secure by any other means heretofore available. This instrument is the best means available whereby it is possible to differentiate between natural soil corrosion and corrosion from stray currents.

COÖPERATIVE TREATMENT OF ELECTROLYSIS PROBLEMS

When stray current flows into the earth, many different utilities owning underground structures are affected. The problem of electrolysis, therefore, is one which is preëminently adapted to coöperative treatment. When each interest cares for its problems independently, then each is partly undoing the work of others and a condition arises where money is being spent in producing systems that afford only temporary relief.

Such a condition is to be found where each utility attempts to apply a drainage system independent of all other utilities. It is easy to understand how confusion often arises when, say, three companies apply drainage systems independent of each other, and large differences of potential exist between them. The three systems are in many ways in conflict, and very often rapid corrosion takes place.

Troubles in various utilities finally reached a point when it was realized that stray electric currents could be best controlled by coördination of effort on the part of all interests. As a result a committee of representatives of all interested utilities in the East Bay Cities was organized in 1922 to determine the causes of damage to underground structures and recommend measures for their mitigation through means of coöperation among the interests concerned. Such assistance in the way of testing instruments, engineers, draftsmen, field employees, transportation and office space are contributed by the various member organizations. This committee holds monthly meetings to discuss the technical phases in connection with reports of tests and investigations that have been made during the current month and makes recommendations for protective measures. It recommends tests and investigations to be made and indicates the methods to be followed in making such tests and investigations.

Regular surveys are made of the railway systems and the various underground structure systems, and include such measurements as: current of station loads, rail gradients, overall potentials, difference

of potential between rails and underground structures, current on underground structures, difference of potential between different structures and earth current measurements. These tests comprise to date over 2000 twenty-four hour recording charts and 6000 readings from indicating meters. Test on railway systems required over 800,000 feet of wire which had to be strung on pole lines.

In addition to regular tests, this committee also investigates special cases of corrosion and installs pilot wires and drainage cables. Many serious cases have been corrected through committee activities at a minimum of expense to the interests affected.

The work of this committee has rendered valuable service in the installation and maintenance of drainage systems. An agreement was reached whereby drainage cables from the various underground structures were run to the most convenient manhole, either telephone or electric light, and these connected to the negative return on a common bus bar. Such an arrangement makes it possible to insert resistance grids in series with drainage cables in order to equalize the potential between various underground structures.

This committee makes monthly tests of return current on all drainage systems as a precaution against damage from broken drainage connections or unusually large currents being drained due to changes or additions to the various structures. Tests are taken periodically to check the voltage conditions existing between the various structures, and steps are immediately taken to correct any dangerous conditions that might be found.

Coöperative treatment of electrolysis problems has been proven successful in a number of cities throughout the country, and is now generally recognized as representing the best practice in electrolysis prevention.

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POTENTIOMETRIC DETERMINATION OF HYDROGEN ION CONCENTRATIONS IN BOILER WATERS[1]

By Willard N. Greer[2] and Henry C. Parker[2]

The dissociation of water into its constituents, hydrogen ions H^+, characteristic of acids, and hydroxyl ions ^-OH, characteristic of bases, has an important bearing on the properties of salts in solution. According to the kinetic theory, the process is such that, at equilibrium, the rate of formation of the ions from the water molecules is equal to the rate of recombination of the ions. Expressing the equilibrium mathematically, we have:

$$\frac{[H^+] \times [OH^-]}{[HOH]} = k$$

where the brackets [ ] indicate concentrations. Since water is only slightly ionized, the concentration of the undissociated water, [HOH], may be considered a constant at a given temperature, and combined with k. The above equation then becomes:

$$[H^+] \times [OH^-] = K \qquad (1)$$

The constant K has been determined, by a variety of methods, to be 10^{-14} at 22°C. The value of K increases considerably at higher temperatures.

The introduction of an acid into water increases the hydrogen ion concentration, and the introduction of a base increases the hydroxyl ion concentration. In either case, assuming the law of mass action to hold, the equilibrium condition is such that, under the same temperature conditions, equation (1) applies. These considerations show that, whatever the concentration of hydroxyl ions, there are always hydrogen ions present, and we may speak of the hydrogen ion concentration of a solution which is really basic.

[1] Presented before the Boiler Feed Water Studies meeting, Buffalo Convention, June 9, 1926.

[2] Research Department, Leeds & Northrup Company, Philadelphia, Pa.

HYDROLYSIS OF SALTS

The temperature and the constituents of a salt, MeX, determine the degree of hydrolysis in solution. Both anion and cation can react with the ions of water:

$$Me^+ + HOH \rightleftarrows MeOH + H^+ \quad (2)$$

$$X^- + HOH \rightleftarrows HX + OH^- \quad (3)$$

The salts of strong acids and strong bases are largely dissociated. Since such salts are not hydrolyzed to any appreciable extent, the hydrogen-ion concentration of their solutions is about 10^{-7} at ordinary temperatures. Acids and bases affect the hydrogen-ion concentration of such solutions in the same way as that of pure water.

A salt of a weak base and a strong acid will react according to equation (2) and the solution will have an acid reaction. A salt of a strong base and a weak acid will react according to equation (3) and the solution will have an alkaline reaction. In titrating a solution of magnesium chloride, $MgCl_2$, it is evident that sufficient alkali would have to be added to neutralize the HCl formed by the hydrolysis. A similar effect is caused when making an alkalinity determination of a carbonate, such a solution requiring additional acid to neutralize the $Ca(OH)_2$ formed by the hydrolysis.

It is evident that the true neutral point of a solution occurs when $[H^+]$ and $[^-OH]$ are equal, and have a value of 10^{-7} at ordinary temperatures (equation 1). The end point with phenolphthalein, however, occurs when the hydrogen ion concentration is approximately 10^{-8}, and that with methyl orange when the hydrogen ion concentration is approximately 10^{-5}. This shows that when hydrolyzable salts are present a titration with indicators is only an approximate method of determining the acidity or the alkalinity of a solution. A titration may be said to give a measure of the *available* acidity, while hydrogen ion measurements give the true or *actual* acidity of a solution. It is the latter factor which determines the *reactivity* of a given solution. Hence the measurement of *ion* concentration will undoubtedly be necessary before any definite relation can be established between the concentration of boiler chemicals and caustic embrittlement, foaming, corrosion, formation of scale, and other boiler phenomena.

Instead of expressing the hydrogen ion concentration as a negative exponent, Sorensen suggested the use of the term pH, the pH value being the logarithm of the reciprocal of the hydrogen ion concentration, $pH = \log \frac{1}{[H^+]}$. A neutral solution then, has a pH of 7, and the end points of phenolphthalein and methyl orange occur approximately at a pH of 8 and 5, respectively. A solution normal with respect to hydrogen ions has a pH of 0, while a solution normal with respect to hydroxyl ions has a pH of 14.

At the higher temperatures and concentrations the measurements of the ion concentrations become of increasing importance due to the fact that the ionization of electrolytes decreases considerably at these temperatures.[3] This is especially true of the more complex salts, since the ionization of such salts falls off more rapidly than does that of the binary salts. Measuring the hydrogen ion concentration of boiler water at ordinary temperatures does not give a measure of this value at boiler temperatures, but it is usually a much more valuable measurement than the "alkalinity" at ordinary temperatures. (Of course an alkalinity determination at ordinary temperatures does not give a true measure of the alkalinity at boiler temperatures.) The latter does not take into account the presence of salts which may hydrolyze at the higher temperatures and thereby supply sufficient acid for corrosion. Hydrogen ion measurements, on the other hand, do make allowance for these salts, due to their so-called "buffer" action. By "buffer" action is meant the resistance exhibited by a solution to change in pH upon the addition of alkali or acid.

A simple experiment is cited to illustrate the relation between alkalinity and pH of a solution containing a hydrolyzable salt. If just sufficient sodium hydroxide is added to distilled water so that on boiling the solution will remain pink to phenolphthalein, and then a solution of magnesium sulfate, for instance, is treated with sodium hydroxide to give the same alkalinity, the color of the latter will disappear on boiling. If, however, the magnesium sulfate solution is treated with sufficient sodium hydroxide to bring it to the same pH as the sodium hydroxide solution, the former will give a pink color with phenolphthalein on boiling. The results of such an experiment are tabulated below.

[3] Kraus, The Properties of Electrically Conducting Systems, p. 151. The Chemical Catalogue Company, N. Y.

Distilled water with NaOH

Alkalinity = 0.9 cc. H_2SO_4
pH = 9.65
(Pink to phenolphthalein on boiling)

$MgSO_4$ solution

Added NaOH to give alkalinity = 0.9 cc. H_2SO_4 (color disappeared on boiling)
Added NaOH to give pH = 9.65 (color remained on boiling)

Sample of boiler water

Added H_2SO_4 to give pH = 9.65 (color remained on boiling)
Added H_2SO_4 to give alkalinity = 0.9 cc. H_2SO_4 (color disappeared on boiling)

This experiment shows that a boiler, freshly filled with condensate, requires only a small fraction of the alkalinity which is required after the normal accumulation of salts. Control of the boiler water to a given pH would accomplish this. Hence, in cases where the pH of the boiler water is normally kept at a pH of 10.5 or below, it is probable that this type of control would be more satisfactory than alkalinity control. Above a pH of 10.5 the H-ion measurements would probably be found too insensitive.

The large buffer action of a small quantity of salts in water is further shown by a table given by Wilson,[4] who found that, in order to raise Cambridge tap water to a pH of 10, it was necessary to add 40 p.p.m. of sodium hydroxide, while the same requirement for distilled water was only 13 p.p.m. Thus, if the pH of this water, considered as boiler feed water, had been kept constant by hydrogen ion control, there would have been added 27 p.p.m. of caustic to allow for the salt content of the tap water. On the other hand, if the control had been by an "alkalinity" determination, no such allowance would have been made, and the salts would have gone into the boiler with no alkali to compensate for the acid liberated on hydrolysis at high temperatures.

It is not claimed that the excess caustic that would be added by hydrogen ion control would be just sufficient to neutralize the acid liberated at boiler temperatures, but this allowance would be approximately correct for the following reason. It is well known that the salts which hydrolyze slightly at normal temperatures are the ones which exert the greatest buffer action. Thus the content of sodium chloride would have very little effect on the amount of caustic

[4] Jour. Ind. Eng. Chem., *15*, 128 (1923).

required to bring the boiler feed water to a given pH value. On the other hand, a salt like magnesium chloride would have a much greater "buffer" action and this is the type of salt which would be expected to liberate acid at the higher temperatures.

HARDNESS, ALKALINITY AND pH

The method of determining hardness by the soap test was first proposed by Clark.[5] This method, at best, is only an approximation, and has been criticized by various writers.[6] Especially is this method in error in waters containing appreciable amounts of magnesium. A few samples of water containing known amounts of calcium and magnesium chlorides, in the ratio of two to one, were tested for hardness by the soap method, and it was found that the results were from 30 to 35 per cent low. The results obtained might be termed the "apparent hardness."

The results obtained on treating solutions of calcium and magnesium chlorides, and samples of water from three different rivers, with sodium carbonate and hydrochloric acid, respectively, are shown in figure 1, where the apparent hardness is plotted as abscissae and the pH as ordinates. Curve S was plotted from data obtained on a sample of water from the Schuylkill River, curve W from a sample of the Wissahickon Creek, curve D from a sample of the Delaware River, curve A from a solution containing 0.475 gram of $CaCl_2$ and 0.235 gram of $MgCl_2$ per gallon of distilled water, and curve B from a similar solution containing 0.235 gram of $CaCl_2$ and 0.115 gram of $MgCl_2$ per gallon. Air was previously bubbled through these solutions for a few minutes, to produce as nearly as possible the condition of natural water. The initial pH and alkalinity of each sample is indicated by the point between the arrows, addition of sodium carbonate resulting in an increased pH, and addition of HCl resulting in a decreased pH. It is evident from these curves that the apparent hardness is practically independent of the pH between pH 4 and pH 7.5. It might be said that all waters are hard below pH 3.

There is a more or less general relation between the pH and the alkalinity of natural waters. This is indicated by figure 2, where the pH is plotted as ordinate and the alkalinity as abscissa. The

[5] Chemical Gazette, *5*, 100 (1847).

[6] Hehner, Analyst, *8*, 77 (1883). Pfeiffer, Z. angen. Chem., 193 (1902). Proctor, Jour. Soc. Chem. Ind., *23*, 8 (1904).

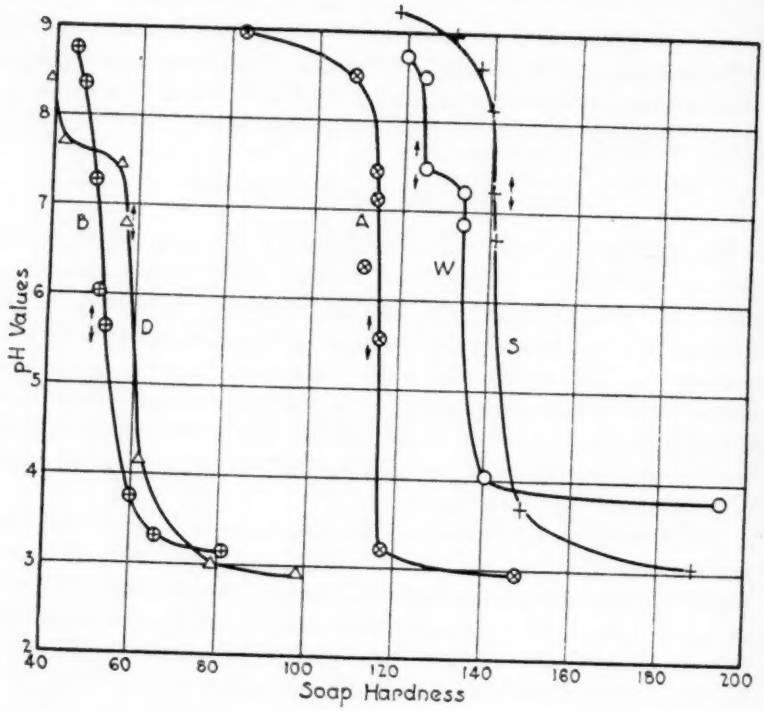
pH Values
Soap Hardness
B
D
A
W
S
9
8
7
6
5
4
3
2
40
60
80
100
120
140
160
180
200

FIG. 1

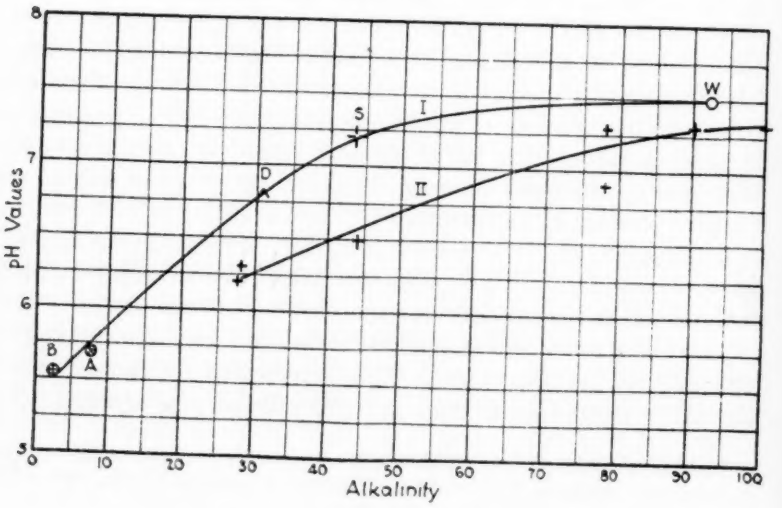
pH Values
Alkalinity
S
I
W
D
II
B
A
8
7
6
5
0
10
20
30
40
50
60
70
80
90
100

FIG. 2

points W, S and D, curve I, represent these values as determined from samples of the Wissahickon Creek, Schuylkill and Delaware Rivers, respectively. Points A and B were determined from solutions containing calcium and magnesium chlorides in distilled water, the composition of A being 0.475 gram $CaCl_2$ and 0.22 gram $MgCl_2$ per gallon, and that of B 0.235 gram $CaCl_2$ and 0.115 gram $MgCl_2$ per gallon. Curve II was plotted from data by Greenfield and Baker[7] obtained on three different rivers in the Middle West.

ELECTROMETRIC DETERMINATION OF H-ION CONCENTRATION

The electrometric method is the fundamental method of determining hydrogen ion concentrations. Other methods of determining H-ion concentration are referred to the electrometric method as a standard. Colorimetric methods give approximate values and may be used where only rough measurements are desired. Of course, colorimetric determinations cannot be used where a continuous record of H-ion concentration is desired, but may be used as a rough check on electrometric determinations. The electrometric method of measuring H-ion concentration consists in measuring the voltage developed when suitable electrodes are immersed in the solution. It is beyond the scope of this paper to discuss in detail the derivation of the equations relating to pH and the potential difference between electrodes.[8] It will be sufficient to give a few fundamental relations.

The fundamental reference electrode is the hydrogen electrode. A noble metal, platinum generally being used, coated with platinum black may be made to serve as a hydrogen electrode. When it is saturated with hydrogen and immersed in a solution containing hydrogen ions, there is exhibited a difference of electrical potential between solution and electrode which is dependent upon the concentration of hydrogen ions. We have no means of measuring such a single potential, but if we have two such electrodes, in separate containers and connected by means of a "salt bridge," we can measure the total E.M.F. We can show how this E.M.F. varies with the concentration of hydrogen ions from a derived equation.

$$\text{E.M.F.} = 0.000{,}198{,}37\ T \log \frac{C}{C'}$$

where T is the absolute temperature, and C and C' are the H-ion concentration.

[7] Jour. Ind. Eng. Chem., *12*, 990 (1920).

[8] For a complete discussion see, Clark, The Determination of Hydrogen Ions. Williams and Wilkins, Baltimore.

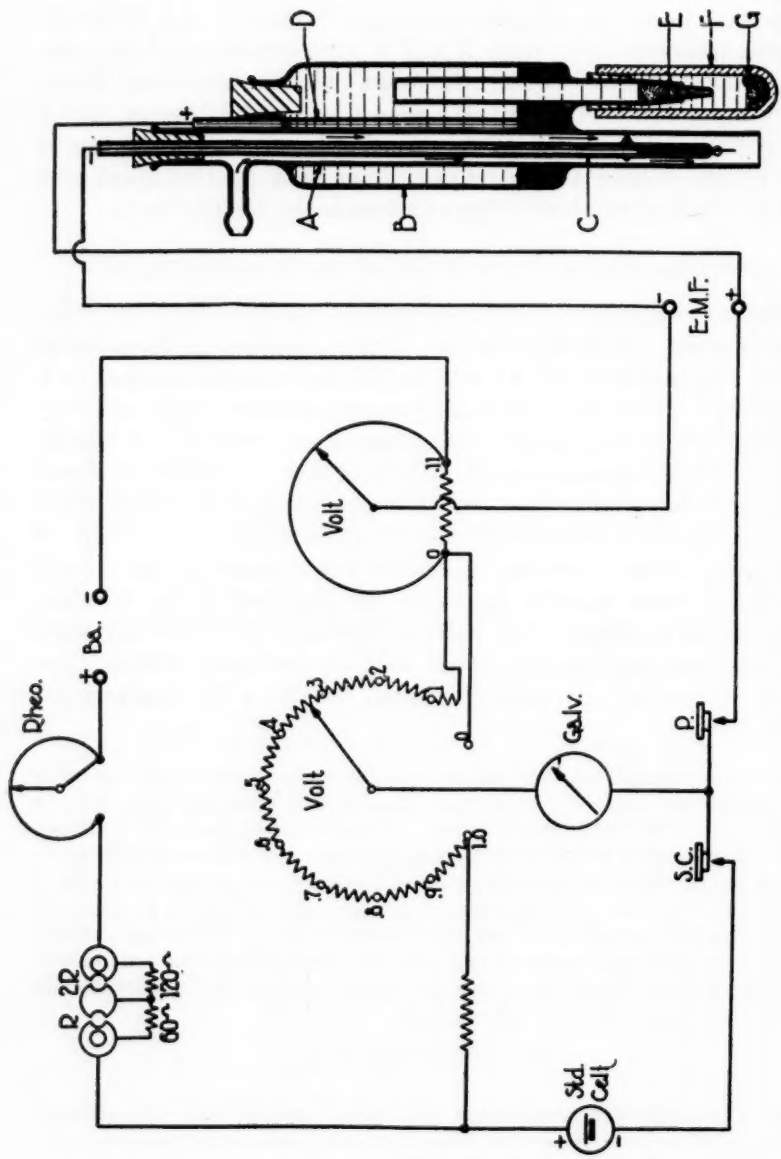

FIG. 3. DIAGRAM OF POTENTIOMETER CIRCUIT AND ELECTRODES

If measurements are carried out at 25°C. the equation becomes E.M.F. = $0.0591 \log \frac{C}{C'}$.

Instead of using two hydrogen electrodes it is more convenient to replace the standard hydrogen electrode with a calomel electrode. This is an electrode of mercury covered with calomel (Hg_2Cl_2) in the presence of a definite concentration of potassium chloride. A saturated solution of potassium chloride is generally used in industrial measurements, since there is less tendency for diffusion to change the concentration, its conductivity is high, and it shows no change in electrode potential between 5° and 60°C., except that which can be corrected by the temperature coefficient. At 25°C. the mercury of the calomel electrode is 0.246 volt more positive than the platinum of the normal hydrogen electrode. The voltage of the calomel electrode does not vary with changes in the hydrogen ion concentration of the solution, as does the hydrogen electrode. The equation becomes:

$$\frac{\text{Observed E.M.F.} - 0.246}{0.0591} = \text{pH} \qquad (4)$$

As a means of measuring the E.M.F. between two such electrodes, a potentiometer is used. The outlines of a combined type of calomel electrode and hydrogen electrode[9] and a diagram of a potentiometer circuit are shown in figure 3. Electrical connection to the calomel electrode is made through *D*, and to the hydrogen electrode through *C*. The hydrogen is bubbled in through the tube *A*. *F* is a porous cup containing a saturated solution of KCl above a few crystals of KCl, *G*, and forms a salt bridge to the calomel electrode, liquid connection being made through the ground glass plug *E*. To measure the voltage of the electrodes it is only necessary to immerse the combined cell in the solution to a depth sufficient to cover the platinum electrode, bubble hydrogen through the solution around the electrode, and read off the voltage with the potentiometer. The voltage reading may be converted to pH units by means of equation (4), by an H-ion calculator, or read off directly from a pH-voltage chart, figure 4. Such a cell is used for intermittent measurements. The potentiometer can be made to read in volts, or directly in pH units.

FIG. 3. DIAGRAM OF POTENTIOMETER CIRCUIT AND ELECTRODES

ELECTRODES

The hydrogen electrode is the only electrode which will cover the entire pH range but, unfortunately, is not suitable for use in a flowing solution without some method of presaturating the solution with hydrogen. There are several substances which have been found to "poison" this electrode, such as oxidizing substances, some organic compounds, and ions of metals more "noble" than hydrogen. There are, however, a great many industrial processes in which the

[9] Parker and Dannerth, Ind. and Eng. Chem., *17*, 640 (1925).

hydrogen electrode is applied, among which might be mentioned tanning, baking, etc.

The tungsten electrode[10] is apparently the most free from poisoning effects. It is best used in a flowing solution, and is adapted for intermittent measurements only by following a definite procedure. Its accuracy, however, is not greater than ±0.1 pH, and it is not satisfactory for use in solutions more acid than pH 5. A flow channel carrying a saturated calomel cell and tungsten electrode is shown in figure 5. The pH-voltage relations of the tungsten electrode are shown in figure 4.

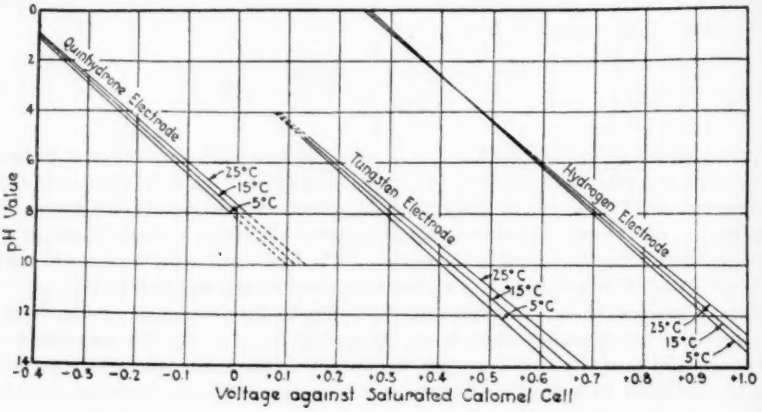

FIG. 4

For intermittent measurements the procedure used is to keep the electrode immersed in a stable buffer solution of approximately the same pH as that of the test solutions, removing the electrode only during the time of use. When used in a flowing solution an electrode is introduced into the cell (or is placed in a buffer solution) twenty-four hours before being connected to the recorder. Experience determines how often, in general, a new electrode will have to be introduced. The usual life of the tungsten electrode in boiler feed water is two weeks.

[10] Baylis, Jour. Ind. Eng. Chem., *15*, 852 (1923). Parker, Jour. Ind. Eng. Chem., *17*, 737 (1925). Parker and Baylis, Jour. Amer. Water Works Assoc., *15*, 22 (1926).

The quinhydrone electrode[11] is not so subject to "poisons" as is the hydrogen electrode, but is not applicable in solutions more alkaline than pH = 8. In a few cases measurements may be made

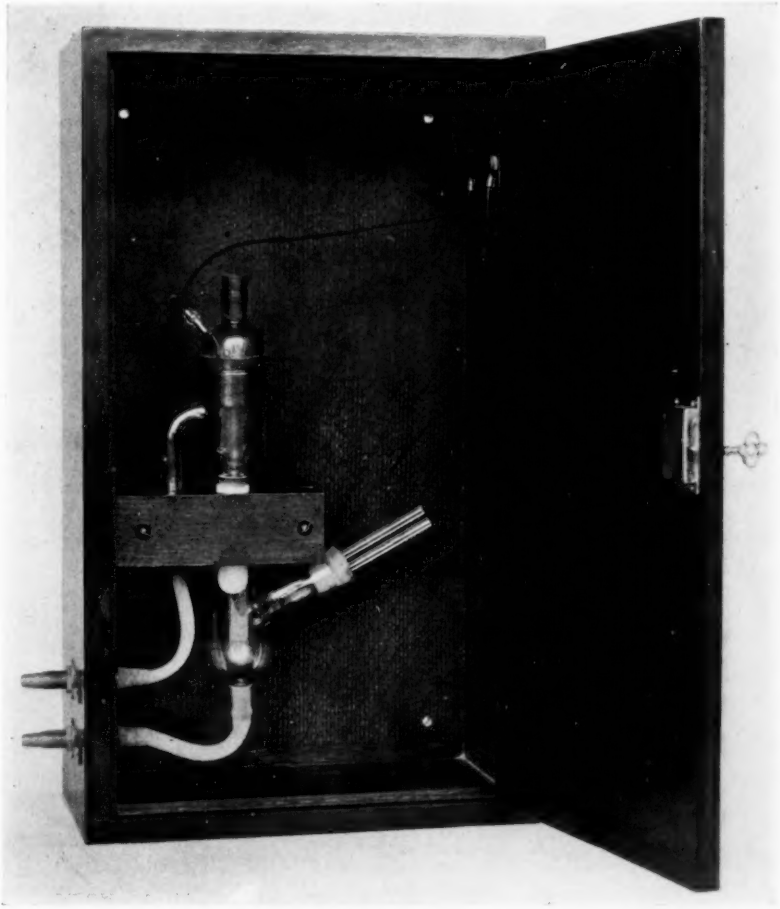

FIG. 5. FLOW CELL

in more alkaline solutions, provided the measurements are made quickly and the first reading is taken as being correct. With this

[11] For bibliographies on the quinhydrone electrode see, Billman, Trans. Faraday Soc., *19*, 676 (1924), or Kolthoff and Furman, Potentiometric Titrations, p. 220, John Wiley & Sons, N. Y.

electrode an error is introduced, if there is a high concentration of salts present, but this error is always in the same direction. This fact does not prohibit its use in such a case, since the relative value will remain the same, if a series of measurements are made. The combined type cell, figure 3, may be used for a quinhydrone elec-

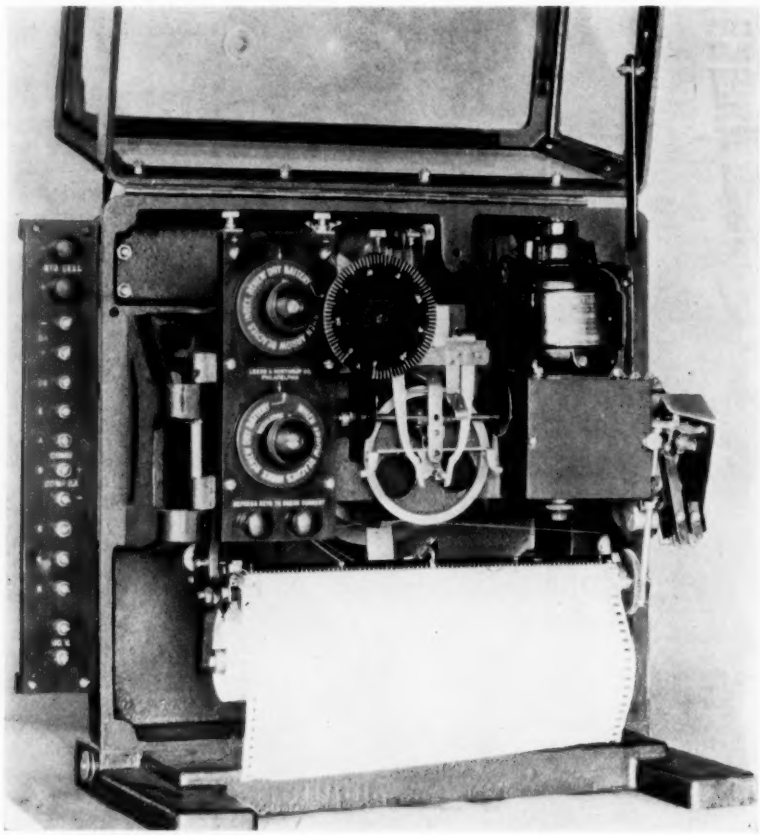

FIG. 6. RECORDING POTENTIOMETER

trode,[12] (a gold electrode is recommended in place of platinum) if a few cc. of saturated quinhydrone solution, or a few crystals of quinhydrone, are added to the test solution. The quinhydrone electrode

[12] Parker and Greer, Preprint No. 2, April, 1926, Amer. Electrochemical Society.

can also be applied for measuring the pH of a flowing solution. The simplicity, ease of manipulation, freedom from "poisoning" and accuracy, make this electrode ideal for a large number of industrial applications.

RECORDING pH

In processes where a continuous record of the pH is desired, use is made of a recording potentiometer, figure 6. The titration curves of samples of boiler feed water with H_2SO_4, using such a recorder, are shown in figure 7. Curve A was obtained by adding H_2SO_4 at a

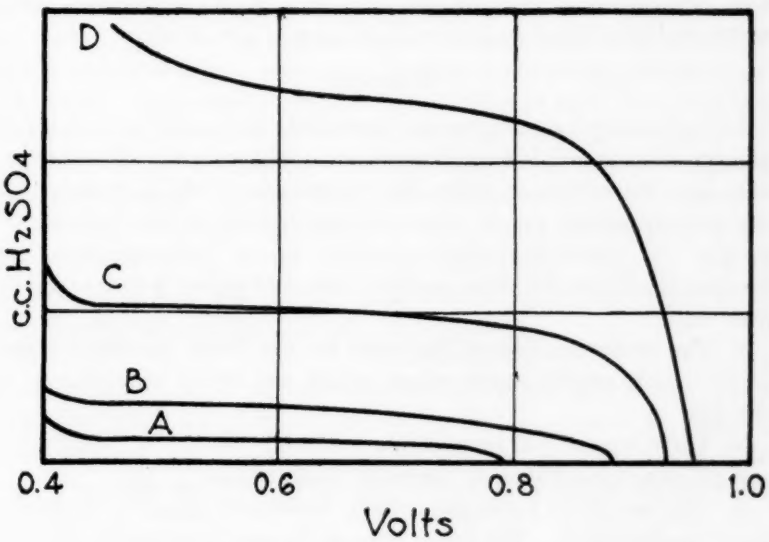

FIG. 7. TITRATION CURVES OF BOILER WATERS

constant rate to a sample from a boiler whose feed water had no pretreatment, curves B and C with boiler feed waters previously treated with caustic soda, and curve D with lime and soda treated feed water. The original pH of these samples were A = 9.65, B = 10.8, C = 11.6, and D = 11.9.

The use of a recorder-controller potentiometer will be discussed in a subsequent paper on the automatic control of H-ion concentration of boiler feed water.

If the pH of boiler water is maintained at a value of 9 to 10, pH measurements will give an indication of an excess or deficiency of

caustic. At higher pH values, however, the change in pH with increased causticity is too small to be of real value, as is indicated by curves C and D, where the difference in pH is only 0.3, whereas the difference in alkalinity is considerable.

Perhaps the most important use of pH measurements is in determining the proper treatment when first starting up a boiler. In such cases pH measurements give a much better indication of the amount of chemcal that should be added to compensate for hydrolyzable salts, than do alkalinity determinations. pH measurements will also indicate the building up of salts in the boiler, and may be used as a true indication of chemicals required if the pH does not exceed a value of 10.5

SUMMARY

1. "Alkalinity" measurements have long been used as a method of approximating H-ion concentrations. The presence of hydrolyzable salts introduces an error, the magnitude of which is such that the determinations are of value only for indicating the "available" acidity or causticity. Consequently, H-ion measurements are frequently of greater value in the control of boiler water or boiler feed water.

2. The determination of hardness by the "soap method" gives, at best, only approximate values, which are nearly independent of the pH.

3. There is a more or less definite relation between the "alkalinity" and pH of *natural* waters at the lower "alkalinities."

4. The use of the hydrogen, quinhydrone and tungsten electrodes has been described. The latter two can be used in a flowing solution to give a continuous record of pH.

AMOUNT OF WATER AVAILABLE FROM IMPOUNDING RESERVOIRS[1]

By H. L. White[2]

Many towns in southern Illinois, unless they are located on a large stream, find that the question of a satisfactory water supply is always staring them in the face. This is particularly true in the coal and oil fields. Wells in the mining regions furnish water that is unsuitable for a water supply because of high mineral content and disagreeable taste. As a result, towns in these districts have turned to the impounding reservoir as a solution to their problem. Within the last year or so Carbondale, Carthage, Sesser and West Frankfort have begun using water from impounding reservoirs.

Although many municipalities will be compelled to use surface water stored during times of heavy rainfall, few data on Illinois streams have been published to aid these towns in determining the size of reservoir and the drainage area required.

In order to supply this need, the State Water Survey Division has undertaken the task of collecting precipitation and runoff data. With the assistance of the City of Centralia, through L. W. Lemon, City Engineer, the Water Survey has begun the collection of data from the drainage area which supplies the Centralia impounding reservoir.

The amount of precipitation on the drainage area is measured in a standard rain gauge, the amount of water drawn from the reservoir each day by the city is metered, and the water level in the reservoir is to be recorded on a Stevens recording gauge. The water level is, at present, read once a day by the reader of the rain gauge. An abstract of the data collected is given in table 1.

The State Geological Survey Division, in coöperation with the United States Geological Survey, is assisting by determining the watershed which lies outside of the region for which a topographic map is now published. Within the region for which a topographic

[1] Presented before the Illinois Section meeting, January 27, 1927.

[2] Assistant Engineer, State Water Survey Division, Urbana, Ill.

map has been published, the State Water Survey Division has located the watershed.

H. E. Grosbach, Assistant Engineer, United States Geological Survey, has given information about water level recorders and offered to measure the amount of water which overflowed the spillway.

TABLE 1

Centralia Reservoir data

MONTH	RAINFALL DURING MONTH		WATER USED FROM RESERVOIR DURING MONTH, GALLONS	WATER LEVEL IN RESERVOIR, FEET	GAIN IN STORAGE, GALLONS
	Inches	Gallons on 7 square miles			
1925					
December				102.4±	
1926					
January	3.59	438,000,000	165,000,000	109.0	+306,000,000
February					
March	3.11	379,000,000	51,618,000	110.59	+98,000,000
April	5.04	614,700,000	38,119,500	114.42	+281,000,000
May	0.98	119,600,000	56,304,000	113.08	−107,000,000,
June	1.22	148,800,000	55,154,000	112.0	−79,000,000
July	3.42	417,100,000	65,903,000	110.75	−85,000,000
August	3.82	465,900,000	55,872,500	109.83	−58,000,000
September	8.10	987,900,000	53,288,000	113.18	+230,000,000
October	7.13	869,600,000	55,381,000	114.67	+119,000,000
November*	2.53	308,600,000	57,759,500	115.17	+42,000,000

Note: Table to be revised when actual drainage area is determined.
One inch rainfall from 7 square miles = 122,000,000 gallons.
* Overflowed spillway during month.

With the assistance of the City of West Frankfort, through E. A. Cox, City Engineer, the State Water Survey is collecting rainfall data for the West Frankfort impounding reservoir. The rain gauge is not located at present close enough to the center of the watershed.

It is hoped, that, in the future, engineers who have charge of the design and construction of storage reservoirs will make some provision for collecting precipitation and runoff data, since the expense is not great and the benefits to towns in this region are of considerable value.

DISCUSSION

J. J. WOLTMANN: I have been interested in runoff from Illinois streams for a long time and have been surprised at the meagre data available. Has there been any attempt to determine evaporation from the water surface at Centralia?

H. L. WHITE: No.

G. C. HABERMEYER: Evaporation experiments are so difficult to make unless the right kind of help is available that they have not been attempted at Centralia.

J. J. WOLTMANN: What account was taken of the spillway overflow?

G. C. HABERMEYER: The spillway did not overflow in 3 years. Nearly all of the flood flows could be measured by the rise of water level in the reservoir.

PHENOL TASTES IN CHLORINATED WATER[1]

By L. C. Osborn[2]

The City of Loveland has been sterilizing its water supply for more than fifteen years. Until 1923 this had been accomplished by applying hypochlorite of lime in a rather hap-hazard manner, using a crude dosing apparatus that fed the solution into the transmission main at a uniform rate regardless of the rate of flow of the water. There was no measuring device to give the rate of flow and no storage to take up the peaks and valleys of consumption. The rate of dosage was controlled by bacteriological examinations taken once a week or perhaps once a month depending upon the season and the last result.

All this time there were intermittent complaints about taste in the water. The natural assumption was that the taste was the result of overdosage because of the unknown rate of flow and the fact that each new batch of hypo had a different amount of available chlorine. No thought was given to phenol tastes.

In 1923 the city began the construction of a modern filter plant providing excellent manual control chlorinating apparatus and a good water measuring device. During this construction period the water consumers suffered patiently with raw river water heavily impregnated with hypo, dreaming of the time when they would have the best water plant that money could buy.

Finally the big day came, especially for me. The Wallace & Tiernan man arrived on the job, set up the chlorinating apparatus, gave the operator instructions, turned on the gas and then took the next train out of town. The filter plant operator tore up the old hypo barrels and kept his eye on the water meter, hoping to deliver the real stuff. The customers knew nothing of the change, but the next morning the response was immediate and often profane. The taste was intolerable. A careful checkup on the chlorine apparatus showed that it had performed perfectly, delivering three pounds of

[1] Presented before the Rocky Mountain Section meeting, February 7, 1927.
[2] City Engineer, Loveland, Colo.

gas per million gallons of water. This was cut down to two, and an ortho-tolidine outfit showed no free chlorine after thirty minutes of contact. However, the taste still persisted. In about three weeks it diminished and in a month it practically disappeared. In the meantime, I tumbled to the fact that at the same time the new chlorinator was put in operation, the city had also put into service a new 36-inch creosoted wood pipe line. This pipe, two miles in length was the feeder for the city's new hydro-electric project situated ten miles above the water works intake. The river flow at this time was 75 c.f.s. and probably about 10 c.f.s. flowed through the creosoted wood pipe. The proportion of creosote present in the river water must have been minute and was absolutely unnoticeable before the water was chlorinated. This was the writer's first experience with a phenol taste as such.

Three months later another frightful taste developed over night. The filter plant operator reported everything O.K. and that gas was being applied at less than three pounds per miliion gallons of water. A careful checkup disclosed that the contractor, who was still working at the plant, had conceived the idea of brightening up the paint on the subway gratings by dipping them in a tar paint thinned with gasoline. After dipping they were placed on a shingle roof in the sun to dry, in an hour or so they were apparently dry and were replaced over the filters. The water entering the filters splashed just a little on a small portion of the grates. I cannot see how more than a half teaspoonful of this paint could have gotten into the water which was flowing at more than two million gallons daily. But there is no doubt that it caused the taste.

In September, 1924, the city's new transmission main from the filter to the city was put into operation. This line consists of eight miles of creosoted wood pipe, the upper four miles 20 inches in diameter, the lower four 24 inches in diameter. Before being put into service this main was flushed continuously for a period of about six weeks. As anticipated, a strong taste was noticeable. In fact, it was very disagreeable for about two months when complaints became less frequent. The remarkable feature of this period was that the taste was uniformly present in all sections of the city in spite of the fact that the old main was still in operation. All attempts at reducing the taste by dilution from the old main seemed futile.

In the latter part of December, 1924, a new storage equalization tank, of one and one-half million gallon capacity, located midway

between the filter plant and the city, was put into service. A strong phenol taste again occurred. The tank is of concrete, but the connecting link to the pipe line is creosoted wood, and in spite of the fact that this pipe stood for several weeks full of water which was then changed and wasted three times, it was the cause of the taste.

When the tank was put into operation, the orifice meter at the filter plant became undependable on account of the fact that the pipe line was not always full. Consequently, determining the chlorine dosage became an estimating process until a weir was completed. During this period a phenol taste was present, the complaints indicating a varying intensity.

During the summer of 1925, the taste would disappear only to recur inexplicably. At the present, the same is true; however, let it be said that some individuals testify that a disagreeable taste is always present.

WATER SUPPLY AND STREAM DATA

The Loveland water supply is procured from the Big Thompson River. The drainage area is possibly 1000 square miles. The watershed is entirely mountainous, the normal stream consists of snow and spring water, very soft, cool and clear. The stream flow varies from 15 c.f.s. in winter to 2000 c.f.s. at early summer flood peak. The watershed is sparsely populated, having a permanent population of perhaps 500 persons; in the summertime the peak is possibly 20,000 persons. The only village is Estes Park. There is not a factory on the watershed and hence no problem of industrial waste. Estes Park sewage is treated before being emptied into the river. The City of Loveland patrols the watershed, attempting to prevent any nature of stream pollution. Bacteriological tests, however, nearly always indicate the presence of B. coli in the river water.

The source of phenol compounds causing the recurrence of chlorophenol tastes in Loveland's water is a matter of conjecture, but in my opinion may include the following: (*a*) motor wastes and washings from Estes Park garages; (*b*) chemical compounds contained in Estes Park sewage; (*c*) oils thrown off by decaying organic matter. The only indication of any such pollution is an oily appearance on the surface of the water in the river immediately below the city diversion dam. On account of irrigation diversions, it is only possible to see this during certain seasons.

PREVENTIVE MEASURES

No preventive has been discovered as far as the application of chlorine is concerned. The present policy is to use as small an amount as possible consistent with safe results. An attempt is made to maintain about 0.1 part per million residual chlorine. Daily bacteriological examinations are made to check results. The one attempt at superchlorination was disastrous from the taste standpoint

The only conclusions that I care to make are:

1. Loveland's raw water before being chlorinated does not taste.

2. Chlorine alone does not cause the water to taste, otherwise it would taste continuously.

3. It requires a ridiculously small amount of a phenol compound in chlorinated water to cause a taste.

Taking into account the source of many different complaints and taste examinations, the following statements seem to be reasonable, but are by no means conclusive.

1. The intensity of a chloro-phenol taste in water is greatest when the greatest time has elapsed since chlorination (within limits, of course). This is shown by

a. At no time has such a taste been detected in the chlorinated water at the filter plant

b. The taste seemed to be augmented by placing the storage tank in service

c. The taste seems to be more intense during a low period of consumption

d. The greatest complaint is from customers tapped on the larger pipe within the distribution system

e. The taste is greater in the morning while the water that has stood overnight is being consumed.

f. Farmer customers securing water from the city supply, when the same has a strong phenol taste, have stated that when stored in cisterns the taste is greatest after one week, when it gradually disappears.

2. Phenol tastes may be caused by the action of chlorinated water on sediment scale or coating in the pipe in the distribution system. This seems reasonable by complaints purely local in character and their nature causes the writer to suspect new cast iron mains.

Practically all Loveland water consumers know that chlorine is used as a sterilizing agent. I am of the opinion that tastes, real and

imaginary, are magnified by this knowledge. The great difference of sense of taste in individuals and the close association of taste and odor make it difficult to tell whether the water is good or bad and what the cause may be?

SPORE BEARERS IN THE SPAVINAW WATER SUPPLY

By R. L. Ginter[1]

The Spavinaw Project was placed in service November 17, 1924. The 400-square-mile water-shed collects the water in a 20-billion gallon reservoir which is located approximately 65 miles to the east and north of Tulsa. From this reservoir the water flows to the Mohawk Pump Station where it is chlorinated, aerated and then pumped four miles to an inclosed high pressure reservoir located at the north end of the city

During the past few years considerable work has been done by various investigators on spore-bearing lactose splitting organisms which occur in water supplies. The water-works man is now aware of the limitation that must be placed on the interpretation of the standard presumptive test.

The descriptions of the various spore-bearing lactose fermenting organisms are omitted here. The reader is referred to the appended bibliography on the subject.

During the first month of the Spavinaw operation positive presumptive tests which did not confirm were obtained from water samples which had been treated with 0.4, 0.6 and 0.8 part per million chlorine. In all cases the gas production was more rapid in the chlorinated water fermentation tubes than it was in the untreated control water tubes. The trouble was apparently due to the presence of lactose splitting organisms other than Bacterium coli, for the laboratory record showed that the supply was not contaminated. The untreated water had a B. coli index of 0.1 per cubic centimeter and the average count on agar at 37°C. was 490. Throughout the year the B. coli index does not vary appreciably from the mean, whereas the count increases during the summer months and decreases through the winter season.

Positive presumptive tests were also obtained in the laboratory after chlorinating samples of the untreated water with various amounts of chlorine up to 2.0 parts per million. Again it was observed that the gas

[1] Chemist, Water Department, Tulsa, Oklahoma.

production on standard lactose broth was more rapid than it was on the control untreated water. This indicates that organisms in the untreated water which are killed by chlorine inhibit to a certain extent the microörganism in question. Prepared slides disclosed the presence of large Gram-negative oval organisms and, although these first cultures were not pure, the writer felt justified in reporting to the water department that the A. P. H. A. presumptive test was not indicative of the presence of Bacterium coli in the chlorinated water.

ISOLATION METHOD

Forty-eight hour positive lactose broth tubes were subcultured to Endo or eosin methylene blue agar plates. Transfers were made after forty-eight hours to a lactose broth tube and an agar slant by fishing from the edges of the growths on the Endo or eosin methylene blue agar plates. If gas was produced here on the lactose broth and the stained slide did not disclose Bacterium coli a transfer from this forty-eight hour agar slant was made to a third lactose broth tube which was then heated fifteen minutes in a water bath at 90°C., cooled and then incubated for forty-eight hours at 37°C. Agar plates were then streaked from the positive lactose broth tubes at this stage. Agar slants for study were then prepared by fishing from the edges of these forty-eight-hour agar plate growths. This method is essentially the same as that used by Norton and Weight.

MORPHOLOGIC AND CULTURAL CHARACTERISTICS

The organism is approximately twice the length of Bacterium coli and is oval in shape. Gram-negative cells occur singly, in pairs, but never in chains. The cells from forty-eight and seventy-two hour agar slants show a single spore, oval in shape and centrally located. Motility was observed in the majority of cultures. The attempts to grow this microörganism anaerobically failed. Indol tests were negative. The Voges Proskaur tests were positive and methyl red negative. All cultures studied liquefied gelatin after five days. Growths obtained on Endo and eosin methylene blue agar plates were not characteristic of Bacterium coli; on the former the growth was scant, somewhat branched and usually pink at the edges; and on the latter the growth was scant, light in color and branched. The metallic sheen produced by Bacterium coli on these media was entirely absent from growths of this organism on Endo and eosin methylene blue agar. Acid colonies were produced on purple lactose agar. Growth was not obtained in the Koser citrate solution.

Acid and gas in forty-eight hours were produced on lactose, sucrose, dextrose, mannite and starch. Fermentation results on dulcite and lactose bile were negative in ninety-six hours. Pure cultures of Bacterium coli isolated from human feces and water were used for control.

RESISTANCE TOWARD CHLORINE AND COPPER SULPHATE

An emulsion was prepared by looping the growth from a one-hundred-twenty-hour lactose agar slant to approximately 15 cc. of Dunham's peptone solution which was then introduced into 2000 cc. of sterile sodium chloride solution (8.5 grams per liter). The whole was well mixed and 200 cc. aliquots were then treated with various amounts of chlorine and copper sulphate. Each portion was shaken forty-five seconds, allowed to stand twenty minutes, and then tubed and plated. It was found that neither 17 parts per million chlorine nor 19 parts per million copper (in terms of metallic copper) killed this organism.

FREQUENCY OF ATYPICAL STRAINS

From 191 samples of chlorinated water collected from service taps, 41 per cent gave positive presumptive tests, 66 per cent of the positive presumptives did not confirm and 34 per cent confirmed. Thus atypical lactose splitting strains were present in 27 per cent of the total chlorinated samples collected. Ten pure cultures of this organism were isolated and studied, although all the atypical strains did not prove to be this oval Gram negative organism. In some cases complete failure of growth on Endo and eosin methylene blue agar was obtained and in other cases the procedure was dropped if gas was not produced on the lactose broth tube (subculture from Endo).

MEDIA USED

All agars were obtained from Digestive Ferments Company. The carbohydrates with the exception of the starch were obtained from the same company. The gelatin and ox gall were Digestive Ferments Company products. The sugar broths were adjusted to pH 7.2 to 7.5. The Koser citrate solution was made from C. P. Chemicals. The peptones were obtained from Digestive Ferments Company.

CONCLUSIONS

1. The organism studied is very similar to the one described by Norton and Weight.

2. No sanitary significance is attached to this organism for other workers have disclosed some evidence that the soil is at least a

secondary source of organisms similar to the one described in this paper.

3. Evidence that 5 per cent bile inhibits Bacterium coli has not been obtained.

4. It is not suggested here that the Standard sanitary water methods should be made more severe or more lenient. A change in the presumptive test, however, involving the use of a low per cent bile medium similar to that used by Dunham, McCrady and Jordan, would result in a saving of routine time. Such a change would also increase the dependence the water-works man places on the presumptive test.

ACKNOWLEDGMENTS

Appreciation is here expressed for the kind assistance of J. J. Weight, School of Medicine, University of Utah, in examining two of the cultures.

Appreciation is further expressed for the coöperation of water department officials.

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REPORT OF STANDARDIZATION COUNCIL

During the past year activities under the Council have related largely to the work of the committees on Standard Methods of Water Analysis and of Boiler Feed Water Studies; and to the appointment of two new committees on Standpipes and Water Towers and on Steel Pipes. These new committees were appointed following an investigation and report by special committees on plan and scope as well as general desirability of appointing such committees on the respective topics.

COMMITTEE ON STANDPIPES AND WATER TOWERS

A special committee consisting of J. E. Gibson, Chairman, Nicholas S. Hill, Jr., George H. Fenkell, H. F. Huy and Robert E. McDonnell recommended that a committee be appointed to prepare a standard form of specifications covering steel standpipes and water towers on a comprehensive basis and in December, 1926, the following committee was appointed:

James E. Gibson, Chairman, General Manager, Water Department, Charleston, S. C.
C. D. Abbott, Associated Factory Mutual Fire Insurance Company, Boston
James H. Edwards, American Bridge Company, New York City
George P. Horton, Chicago Bridge & Iron Works, New York City
L. R. Howson, Alvord, Burdick & Howson, Chicago
H. F. Huy, General Manager, Western New York Water Company, Buffalo
J. O'Leary, Pittsburgh-Des Moines Steel Company, New York City

STEEL PIPE COMMITTEE

The special committee appointed at Buffalo to deal with the steel pipe situation, consisting of Allen Hazen, George H. Fenkell, Clinton L. Bogert, Thomas H. Wiggin and Frank A. Barbour, Chairman, recommended the appointment of a committee to deal with this subject particularly as related to the following:

1. The collating of all existing information in reference to steel pipe lines now in use.

2. The selection of certain pipe lines as best available for further testing, with due regard to the desirability of wide geographical distribution and the representation of as many variations as practicable in the character of water carried.

3. The establishment of a standard method of testing for hydraulic losses with suitable variation for different conditions.

4. The selection for each pipe line of some group of engineers—perhaps a Section of the American Water Works Association—which can best undertake the testing of a particular line or lines under the general supervision of the Committee.

5. If, in order to carry on the tests, it is necessary to develop a field party, or a traveling supervisor of tests, the making up of a budget of the probable expense and ascertaining whether the manufacturers are willing to support the investigation to this extent.

6. Periodical reports to the Association of the results obtained.

In March, 1927, the following committee on steel pipe lines was appointed:

J. Waldo Smith, Board of Water Supply, New York City
Clinton L. Bogert, Consulting Engineer, New York City
George H. Fenkell, General Manager, Water Department, Detroit, Mich.
H. Seaver Jones, East Jersey Pipe Company, New York City
George W. Pracy, Spring Valley Water Company, San Francisco
Fred C. Scobey, General Irrigation Engineer, U. S. Department of Agriculture, Berkeley, Cal.
Frank N. Speller, Metallurgical Engineer, National Tube Company, Pittsburgh, Pa.
E. E. Wall, Consulting Engineer, St. Louis, Mo.
Charles V. Witt, Witt Steel Company, Greenburg, Pa.

STANDARD METHODS OF WATER ANALYSIS

Chairman Hinman reports that during the past year this committee has devoted the greatest amount of attention to the following topics:

1. The use of brilliant green lactose bile medium as a secondary fermentation test in the detection of organisms of the colon group. The idea in using this procedure is to make easier and speedier the detection of organisms of this group and their partial confirmation in laboratories which are not supplied with highly trained assistants.

2. The detection of phenols, which are so annoying in connection with taste development following chlorination.

3. The determination of iodine, which has received so much attention in connection with goiter surveys.

4. Further studies on the ortho-tolidine and soap tests for free chlorine and hardness of water respectively.

5. Studies on microscopic examinations of water with the use of the Foerst centrifuge.

Plans have also been developed for cooperating with the Committee on Boiler Feed Water Studies, particularly as related to the determination of dissolved oxygen and free carbon dioxide.

Further investigations have also been made of the periodate method for manganese and free chlorine determination, as well as additional studies on alkalinity and hydrogen ion concentration correlation.

BOILER FEED WATER STUDIES

Substantial progress has been made at the four meetings of the Executive Committee directing this undertaking and comprising representatives of the following organizations which are now officially sponsoring this movement:

American Water Works Association
American Society of Mechanical Engineers
American Railway Engineering Association
American Boiler Manufacturers Association
National Electric Light Association
American Society of Testing Materials

Progress reports of the nine sub-committees were presented at the December, 1926, meeting of the American Society of Mechanical Engineers in New York and the reports in part or in full have appeared in Mechanical Engineering, Railway Age and in the Journal of the American Water Works Association. Current monthly bibliographies have been prepared through the cooperation of Sub-committee 9 and the Publication Committee of the American Society of Mechanical Engineers. This material is being published in the journals of the associated engineering societies.

On June 8 at the convention of The Association in Chicago, an all-day session will be devoted to activities related to the work of this committee which is progressing at an increased rate, so that a full-time stenographer seems necessary in the early future in order to carry forward the work successfully. Contributions of $300 for the needs of this committee have been arranged for with several of the sponsor organizations.

At a meeting of the Executive Committee in December, 1926,

it was found to be the consensus of opinion that the undertaking warranted appropriation for the establishment of a series of paid research studies at several universities equipped for such work. A Finance Committee has been appointed consisting of the following:

F. N. Speller, Metallurgical Engineer of the National Tube Company
C. R. Knowles, Superintendent of Water Service of the Illinois Central Railroad
A. J. Authenreith, Vice-President of the Middle West Utilities Company
A. E. White, Director of Department of Engineering Research, University of Michigan
J. B. Romer, Chief Chemist of The Babcock and Wilcox Company
S. T. Powell, Consulting Chemist, Chairman

Increasing interest is being manifested in the work of the committee on Boiler Feed Water Studies. Its reports have been widely circulated and demands for them have been received by its chairman from all sections of the country.

ABSTRACTS IN THE JOURNAL

Some difference of opinion is found among the members of the Association as to the advisability of continuing the abstracts as now appearing in the Journal. They are highly appreciated by some, but there seems to be others who prefer to see the space in the Journal occupied in other ways. The Council will have to decide at the Chicago convention whether these abstracts are to be continued at an expense which will be somewhat greater in the future than hitherto or whether the prevailing view of the Association would be for the discontinuance of this activity which was started under the direction of the Council in 1922.

Council will welcome assistance in the determination of this question and it desires to have this subject voted upon separately when this report is presented at the convention.

STATUS OF MANUAL OF WATERWORKS PRACTICE

The first printing of the Manual with an edition of 2500 copies was exhausted at the end of September, 1926, one year after its first appearance. A second printing of 1579 copies was made during October last and on April 15, 1927, 505 of them had been sold.

The Council has not been able to form a definite opinion as to the wishes of the membership concerning a revised edition, as compared with additional reprintings of the first edition. Some members

think that the usefulness of the Manual will be enhanced if effort is limited to directing attention to it among the water works industry so as to increase its use among various workers, particularly members of water boards, superintendents and operating men. Others think that it would be helpful to rewrite portions of the Manual for the purpose of bringing the material more nearly up to date and condensing it to a substantial degree.

The Council desires to secure an adequate record of what the membership desires and to this end proposes to request the Secretary of the Association to write promptly to the chairman of each geographical section, of each national division and of the Manufacturers Association, inviting each to send a delegate to a conference which the Standardization Council proposes to hold at 4:30 p.m. on Monday, June 6, at the Chicago convention to develop a plan for ascertaining the wishes of the membership as to the future of the Manual.

The activities of the Council during a period of 5 years in securing material for the book in its present form have led some to believe that it would be wise to leave matters in abeyance until the membership voluntarily indicated its desires as to procedure. On the other hand, it is pointed out that what the members really think about the Manual is not likely to come to the front, unless there is some canvassing agency set up to ascertain systematically what the wishes are of the membership, not only as it assembles at its annual conventions, but as its members gather at various meetings of the sections throughout the country.

Council does not propose to be hurried in taking any steps as to revision of the Manual, but will welcome comments from all sources and will be glad to have the benefit of them at the conference in Chicago when, with the aid of the delegates from the different sections and divisions, it is hoped that there may be set up an active representative canvassing committee which will bring from all groups helpful information to the Council for its consideration in the premises.

FRANK A. BARBOUR,
W. S. CRAMER,
W. W. DEBERARD,
E. E. WALL,
GEORGE W. FULLER,
Chairman.
MALCOLM PIRNIE,
Secretary.

DISCUSSION

SPECIFICATIONS FOR CAST IRON PIPE

In discussion on page 755 of the December, 1926, JOURNAL, J. N. Chester briefly recommends four "classes" for 12-inch water mains. These are supposed to meet the requirements for pressures, heads, etc., established by or credited to The American Water Works Association many years ago. The subject of "classes" is not altogether new, or at least new to the JOURNAL. Several years have passed since that particular size, 12-inch, was subjected to examination and review[1] with respect to classes under conditions somewhat carefully set forth. Would it be unreasonable to beg the author to look over that earlier discussion, criticise it deservedly, assign it to a proper place, or give it his besought approval?

At that time I stated, among other things:

> In these brief notes let only one size (12-inch) and but one quality of iron (tensile strength, 18,000 pounds) be considered. For 12-inch inside diameter pipe, "Class A" shows a factor of safety of 37 against bursting pressures. But for the risk in handling the pipes that factor might safely be less than half as great. "Class B" shows a factor of safety of 21 for the specified head of 200 feet. It is fairly evident that if a pipe can be transported and safely laid where the head is to be 100 feet the same pipe can be transported and safely laid where the head is 200 feet. It is also clear that if we could discover an American Water Works Association authority for using 12-inch pipes under a factor of safety of 18 instead of 21, "Class A" pipe could be substituted for "Class B," and "Class B" would go out altogether. That would be a marked advantage.
>
> Skipping over one class for a moment, consider "Class D" for a head of 400 feet. Transportation and laying do not call for special increments in "Class D" pipes. The factor of safety for "Class D" is 13. Now it may be said that if a factor of safety of 13 is suitable for 400 feet head, a factor of safety of 18 is proper for 200 feet head, and "Class B" does go out. There is still another class, "Class C." If "Class A" pipe be substituted for "Class C" pipe, the factor of safety with 300 feet head would be 12.46. It might with general consent be said that if a head of 400 feet demanded a factor of safety of 13, a distribution system under 300 feet head would be reasonably secure with a factor of safety of 12.46. Then there would be two classes instead of four classes. "Class A" for pressure up to 300 feet and "Class B," as the present

[1] JOURNAL, 7, 1920, pages 366 and 765.

"Class D" would then be called, for service up to heads of 400 feet, and except for the thickened walls to prevent breakage in laying "Class A" the factor of safety would be fairly uniform throughout. Besides this conforms to average experience. No one would hesitate to lay a main under a head of 300 feet when assured that the factor of safety was twelve, that the metal was of good quality and that the pipe had been thoroughly tested under a pressure of 300 pounds to the square inch."

Interest attaches to estimates and notations of the years or decades that must elapse before the American Water Works Association shall avail itself of the merit and advantages incident to the use of factors of safety in its designs and specifications for cast iron water pipe and special castings.

H. F. DUNHAM.[2]

[2] Civil Engineer, New York, N. Y.

A MODEL BOND LAW

Editorial Comment

The incurrence of indebtedness by municipalities and other political subdivisions of the state has been the subject of almost as many varieties of legislative practice as there are municipalities. The financing of public improvement projects through the issuance of long term securities is in many states restricted in minute degree, although not always in accord either with administrative wisdom or sound financial practice, while in other states it is subject to no restrictions. In these latter groups, the procedure in the incurrence and subsequent payment of debts for municipal projects is subject to the vagaries of lay and professional individuals, in many instances unfamiliar either with the theory or the practice of municipal finances.

It is all the more gratifying, therefore, that the National Municipal League of New York City has recently submitted, through its committee on Municipal Borrowings, a draft of a Model Bond Law. This draft is the result of over five years of deliberations on the part of a committee representing financial, legal, legislative and administrative groups. The text of this model act represents the consensus of opinion of this group of experts, as to the purposes for which political entities may be authorized to borrow money; as to the term and type of bonds to be issued for such purposes; and as to the provisions which should be made for sale and for retirement. Such a statewide bond law is proposed in order to bring all localities to somewhere nearly a uniform standard practice.

Although the proposed act contains no particularly novel features, it offers a guide to public officials who may be interested in accepting the lessons of experience and in eliminating the existing statutes which place municipalities at a disadvantage in the bond market. This suggestion of the committee for uniform and simplified practice is well worth the attention of the reader.

Although there are some items in the proposed act upon which the experts could not agree, there are sufficient suggestive features therein to be helpful to any who are concerned with the incurrence of municipal indebtedness. The disagreement of the committee is

particularly emphasized in the minority report on the issuance of sinking fund bonds. The majority of the committee goes strongly on record for the issuance of only serial bonds, whereas a minority of the committee believes that "large cities with sound financial traditions should still be empowered to issue sinking fund bonds." There is considerable strength in the statement of the majority that sinking fund bonds have frequently been misused by administrators. There is room, however, for discussion as to whether such bonds should be prohibited by state law in the case of such municipalities which have ample protection against defective and dishonest public administration.

Among other things the model law permits the issuance of bonds only for permanent improvements. Bonds to meet current expenses are forbidden. Included in the act are schedules for the probable life of the property or improvement to be carried out. These schedules are intended to regulate the terms of the bonds.

Another provision, the lack of which has hampered many public expenditures, is that permitting municipalities to sell bonds at less than par, but not less than 95 per cent of par.

Those familiar with the inconsistencies and inadequacies of many municipal improvement enabling acts should receive with considerable interest the model bond law proposed, or some equivalent.

ABEL WOLMAN.[1]

[1] Editor, Journal of the American Water Works Association; Chief Engineer, Maryland Department of Health.

SOCIETY AFFAIRS

KENTUCKY-TENNESSEE SECTION

The second annual meeting of the Kentucky-Tennessee Section convened at the Hotel Peabody, Memphis, Tennessee, on January 19, 1927, with C. E. Davis presiding as Chairman.

In the absence of the Hon. Rowlett Paine, Mayor of Memphis, Vice Mayor T. H. Allen, who is also a consulting engineer, gave the address of welcome. W. S. Cramer, Past President of the American Water Works Association, responded.

The report of the Secretary-Treasurer for the year 1926 was given and it was moved and seconded that the report be accepted.

Topical discussion on the "Method of acquainting the public with its water supply" was opened by F. W. Albert and was participated in by W. S. Patton, W. S. Cramer, and James Sheahan.

Discussion on the "Psychological effect of water works buildings and grounds upon the public in its attitude toward the purity of the supply" was opened by L. S. Vance and was participated in by H. R. Fullerton, R. J. Morton, F. W. Albert, W. S. Patton and W. W. Mathews.

Discussion on "Are valves necessary on all fire hydrant branches and are hydrants used for any purposes other than by the fire department" was opened by E. T. Holman and participated in by F. W. Albert, T. H. Allen, T. H. Gothard, W. S. Cramer and W. G. Stromquist.

Chairman Davis appointed L. S. Vance and G. T. Bogard representing Kentucky and H. R. Fullerton and E. T. Holman representing Tennessee as Nominating Committee. This committee was instructed to report at the afternoon session.

W. G. Stromquist and Albert Clemens were appointed the Committee on Resolutions.

The meeting then adjourned until 1:30 p.m.

A paper on "Relation of Water Supplies to the Public Health" by Dr. E. L. Bishop, Commissioner of Public Health of Tennessee was read by R. J. Morton as Dr. Bishop was unable to be present.

Dr. Bishop's paper was thoroughly enjoyed by all present for it gave many of them a new insight into what the State Health Department of Tennessee is trying to do to improve the water supplies in the state. The paper was discussed by W. S. Cramer, W. S. Patton, F. W. Albert, F. C. Dugan and W. A. Patton.

Col. F. W. Albert, then spoke on "The New Knoxville Water Plant" and illustrated his talk with lantern slides. His talk was extremely interesting in showing the many problems which have to be studied and solved before proceeding with construction of a plant. Many questions were asked by the members as to how various problems had been solved.

The Nominating Committee then reported as follows:

Officers and Directors for 1927; Chairman, W. S. Patton; Vice Chairman, F. W. Allen; Directors, W. H. Lovejoy and S. R. Blakeman.

It was moved and seconded that the Committee's report be accepted and the above constitute the officers and directors for the coming year.

Topical discussions were called for.

Discussion was opened on "What methods are used for following up those hydrants so used that proper inspection may be made on them" by T. H. Allen and participated in by T. H. Gothard, L. S. Vance, F. W. Albert and W. S. Cramer.

Discussion was opened on "Do you maintain close co-operation with the fire department" by W. S. Patton and participated in by T. H. Gothard, James Sheahan and E. T. Holman.

Discussion was opened on "Has there been a campaign inaugurated in your city for fire prevention and are you taking part in this work" by W. S. Cramer and participated in by W. G. Stromquist, E. T. Holman, T. H. Allen, C. N. Harrub, W. S. Patton and Albert Clemens.

The meeting then adjourned until 9:30, January 20.

The meeting was called to order by Chairman Davis at 9:30 a.m. January 20.

"Stream Pollution in Relation to Water Supplies" was the title of the paper read by C. N. Harrub. The paper was discussed in considerable detail by F. A. Mantel, F. W. Albert, F. C. Dugan, A. P. Learned and H. R. Fullerton. A resolution relating to the pollution of streams was offered by Mr. Harrub for action. This was referred to the Committee on Resolutions.

"The Water Supply Problems of Tennessee" was the title of the paper read by H. R. Fullerton.

"Chlorination of Water Supplies" by G. R. Kavanagh was then read.

Discussion was opened on "What size connection should be allowed for private fire protection and should such services be metered" by E. T. Holman and participated in by W. S. Patton, F. W. Albert, James Sheahan, Albert Clemens, W. W. Mathews, and W. A. Patton.

C. R. Knowles, spoke for a short time on the plans of the meeting of the American Water Works Association at Chicago in June and urged every one to attend.

The meeting then adjourned until 1:30 p.m.

W. G. Kirchoffer read a paper on the "Analyses and Tests for Capacity of Water Supplies from Sand and Gravel Formation." This paper was a most instructive one and was discussed in considerable detail by T. H. Allen, A. P. Learned, R. J. Morton and C. E. Davis.

A motion picture entitled "The Modern Moses" was shown by the representatives of the Layne and Bowler Manufacturing Company, Memphis, Tennessee.

"Mosquito Control Measures for Impounded Water Projects" was given by J. A. LePrince, Senior Sanitary Engineer of the United States Public Health Service. This paper was extremely interesting and contained information of much value, especially to those who had impounded water supplies. The discussion was participated in by C. N. Harrub, W. W. Mathews, W. G. Stromquist, F. W. Albert, R. J. Morton, A. P. Learned, H. R. Fullerton, G. T. Bogard and W. L. Webster.

Discussion was then opened on "What is an adequate rate for automatic sprinkler systems" by W. S. Patton and participated in by W. W. Mathews, G. H. Parker, W. S. Patton, F. W. Albert, Albert Clemens, John Callery, J. H. Swope and W. S. Cramer.

The meeting then adjourned until 9:30 a.m., January 21.

The Section was entertained that night by the members of the Board of Water Commissioners, F. G. Proutt, W. J. Mallery, and W. W. Dean. A dialogue by the twin granddaughters of Mr. James Sheahan, a wrestling bout, and interpretative dancing added much to the enjoyment of the occasion.

The meeting was called to order by Chairman Davis at 9:30 a.m., January 21.

James Sheahan read a paper entitled, "The Construction and Operation of the New Memphis Water Plant." Discussion of this

paper was participated in by C. Edwards, F. G. Proutt, A. P. Learned, F. W. Allen, W. S. Patton, C. N. Harrub, J. O. Sallee, W. S. Cramer and T. H. Gothard.

G. H. Parker then opened discussion on the "Standardizing of hose connections." T. H. Gothard, W. H. Cramer and E. T. Holman added to the discussion.

It was then moved and seconded that a limit of ten minutes be placed on all subjects brought up for discussion.

"Scientific Rate Making, How is it Done?" was discussed by F. W. Albert and F. G Proutt.

A. E. Clark opened a discussion on "What is the minimum amount of laboratory work necessary for the smaller plants of Kentucky and Tennessee, and what is the cost of such work, and how can it be handled by the regular operator." It was participated in by C. S. Layson, Jr., T. H. Parker and W. S. Patton.

Discussion was opened on "How often are complete valve inspections made of entire distribution system" by James Sheahan and was participated in by T. H. Gothard, W. S. Cramer, F. W. Albert, F. G. Proutt and L. S. Vance.

W. S. Patton, Chairman for 1927, announced that the meeting place for the third annual meeting would probably be at Louisville, Kentucky and the Committee on Arrangements for the meeting would be W. S. Cramer, Chairman, George C. Bogard and L. S. Vance.

It was announced that the appointment of the Secretary-Treasurer would be made after the meeting of the Executive Committee.

The meeting then adjourned until 1:30 p.m., when the members were taken on an inspection trip through the Memphis Water Works and a trip through the city parks.

The Executive Committee reelected F. C. Dugan as Secretary-Treasurer.

Resolutions were adopted extending a vote of thanks to Vice-Mayor Thomas J. Allen and to James Sheahan for their important part in making the meetings a success; to the Hotel Peabody for courteous hospitality; to the water commissioners of Memphis, F. G. Proutt, J. M. Dean and W. M. Mallory, for providing entertainment facilities; to W. J. Kirchoffer and J. A. Le Prince for the courtesy of presenting two papers of valuable character. The following resolution was also passed.

WHEREAS: The protection of the waters of the state against such pollution as will render them unfit for use as sources of domestic water supply, is, of vital importance to water works men and engineers, and,

WHEREAS: The increasing industrial activity and construction of sanitary sewerage systems, unless adequately controlled, will tend to render these waters unfit as sources of domestic water supply, and,

WHEREAS: The control of the pollution of these waters is a sanitary engineering problem which can best be administered through the Division of Sanitary Engineering of the Health Department of the State,

Be It Resolved: That it is the consensus of opinion of the Kentucky-Tennessee Section of the American Water Works Association that the State Department of Health should be provided with sufficient funds to employ the necessary sanitary engineers and laboratory personnel to enable them the make thorough sanitary surveys of all streams now used, or of potential value as sources of public and quasi-public water supply.

Be It Further Resolved: That copies of this resolution be sent to the State Departments of Health and to the members of the Legislatures of Tennessee and Kentucky.

F. C. DUGAN,
Secretary-Treasurer.

ROCKY MOUNTAIN SECTION

Twenty-six members and sixty visitors attended the first annual meeting of the Rocky Mountain Section, held in Denver, February 7 and 8, 1927. A full and well balanaced program of addresses, technical papers, motion pictures, round table discussions, section business and inspection trips proved interesting and valuable to all who were present.

The Section was exceedingly fortunate in having such capable and well qualified speakers on this program. Among those of national prominence were Beekman C. Little, Secretary of the Parent Association; Samuel A. Greeley and Wm. M. Barr. L. H. Enslow and Wynkoop Kiersted prepared excellent papers which were read at the meeting in the absence of their authors.

In addition to the papers scheduled on the program, one entitled "Orifice Type Meters," illustrated by lantern slides, was delivered at the Tuesday morning session by G. D. Conlee.

At the business session the election of officers and directors resulted as follows: Chairman, Paul E. Strouse, succeeding himself; Vice Chairman, L. C. Osborn, succeeding A. W. Stedman; Secretary-Treasurer, Dana E. Kepner succeeding himself; Directors, terms ending 1930, A. W. Stedman and E. A. Lawver, succeeding

W. S. Rathbun and D. P. Porter respectively. A motion to have a program Committee appointed by the Chairman to arrange for the 1928 meeting was duly passed, and on it were appointed R. S. Sumner, A. D. Mars, Jr. and Prof. C. F. Poe. Motions were also passed directing the Chairman to appoint an editor and a committee to consider a cooperative arrangement between the Section and the Colorado Municipal League. The editor has not yet been appointed, but the Committee on Cooperation consists of P. S. Fox, D. E. Kepner and P. E. Strouse.

After the advantages of membership in Colorado Engineering Council had been mentioned, the Section voted to apply, designating Dana E. Kepner as its representative in case the application is favorably acted upon. Membership in the Council permits a close cooperation between the local engineering societies and provides that each individual member of the various member societies will receive the monthly Engineer's Bulletin.

A resolution was adopted favoring the passage of Senate Bill No. 346, pertaining to the Division of Sanitary Engineering of the Colorado State Board of Health, with two amendments, one striking out that part which transfers the laboratory work from the Division to the State Bacteriologist, and the other providing that vouchers for expenditures of the Division be approved by the Director and by the President or Secretary of the State Board of Health. Another resolution, declaring it to be the opinion of the Section that the Governor should appoint two engineers on the Colorado State Board of Health, was also adopted.

The program follows:

MONDAY, FEBRUARY 7

Morning Session

Address of Welcome on behalf of the City of Denver. Hon. Benjamin C. Stapleton, Mayor of Denver.

Response on behalf of the Section. Chairman Paul E. Strouse.

Water Supplies for Automatic Sprinkler Protection. Karl Eppich.

Phenol Tastes in Chlorinated Water. L. C. Osborn.

Greetings from the Parent Association and from other Sections. Beekman C. Little.

Afternoon Session

Well Water Problems. Paul S. Fox.

Practical Utility of Bacteriologic Control of Water Supplies. Ivan C. Hall.

Methods and Costs of Water Softening. Wm. M. Barr.

Sewage Treatment and Disposal. Samuel A. Greeley.
Should Apparently Safe Water Supplies be Chlorinated? L. H. Enslow.

Dinner Session

Motion Picture, "Your Glass of Water—Are You Sure It is Safe?" Pennsylvania State Department of Halth.
Motion Picture, "A Modern Sewage Treatment Plant." Portland Cement Association.
Discussion—Water Works Legislation in the Rocky Mountain States. Led by D. E. Kepner.

TUESDAY, FEBRUARY 8

Morning Session

The New Mechanical Filter Plant at Ft. Collins, Colo. Wynkoop Kiersted.
Round Table Discussions:
Slush Ice Control, led by A. W. Stedman.
Industrial Wastes, led by D. P. Porter.

Afternoon Session

Trip to Marston Lake Filter Plant, Denver. Courtesy of the Denver Municipal Water Works, R. S. Sumner, General Manager.

WEDNESDAY, FEBRUARY 9

The City of Ft. Collins, Colorado gave an inspection trip to the new Filter Plant in the Poudre Canon.

D. E. KEPNER,
Secretary-Treasurer.

ILLINOIS SECTION

The annual meeting was held at the Abraham Lincoln Hotel in Springfield, January 27 and 28, 1927. The first day was a joint meeting with the Water Works Section of the Illinois Society of Engineers. The total registration was 102, classified as follows: 30 active members of the Illinois Section, 3 active members from other sections, 18 representatives of associate members and 2 representatives of cooperative members.

The program given below was carried out.

THURSDAY, JANUARY 27, 1927

Morning Session

Joint Meeting with Illinois Society of Engineers, L. R. Howson, Chicago, Chairman

Wells in Buried River Valley at Sullivan, Illinois. W. D. P. Warren.
Improvements in Lime Softening Methods at Columbus, Ohio. Chas. P. Hoover.

Water Works Improvement at Streator. F. G. Gordon.
Coördination of Sewage Disposal and Water Purification. Paul Hansen.
The Springfield Water Softening and Treatment Plant. C. S. Timanus.
The Operation of the Springfield Water Purification Plant. C. H. Spaulding.

Afternoon

Excursions under guidance of W. B. Walraven and Frank Sheets, to the water purification plant, sewer construction, sewage pumping stations under construction and in operation, mining of shale, making of brick, Lincoln's Home and Lincoln's Tomb.

Evening

Annual Dinner

Election of Officers.
Address by John Gamber, State Fire Marshal.
The 1927 Convention of the American Water Works Association at Chicago in June, 1927. F. G. Merkle.

FRIDAY, JANUARY 28, 1927

Morning Session

Preliminary Experiments on the Treatment of Lake Michigan Water for Chicago. John R. Baylis.
Water Purification Development at Indianapolis. Harry E. Jordan.
The Iron Removal Plant at Champaign. Frank C. Amsbary, Jr.
Summary on Alum Coagulation. A. M. Buswell.

1:30 p.m.

The Cause and Prevention of Embrittlement of Boiler Plate. Samuel W. Parr and F. G. Straub.
Riverside Water Works. Chas. E. De Leuw.
Methods of Financing Water Works. George Blanchard. Read by Henry Ringness.
Discussion of Financial Problems, led by W. R. Gelston.
Amount of Water Available from Impounding Reservoirs. H. L. White.

The annual business meeting was held after the annual dinner at the Hotel Abraham Lincoln, January 27, 1927. The following officers were elected for the ensuing year: G. C. Habermeyer, Chairman; C. M. Roos, Vice-Chairman; H. E. Keeler, Treasurer, and W. R. Gelston, Trustee (to 1930).

The following resolution was presented by Harry F. Ferguson and was adopted:

WHEREAS: The proper treatment and disposal of sewage and trade wastes is of vital interest in many cases to waterworks men in order that our present and future water supplies may be protected from objectionable pollution, and

WHEREAS: There is now no division of the American Water Works Association established to give consideration to this matter,

Be It Resolved: That the Illinois Section recommends to the American Water Works Association that there be established in the parent association a Division on Sewage and Trade Wastes Treatment and Disposal in so far as such affect or may affect water supplies for domestic or industrial uses, and

Be It Further Resolved: That if Division is established that the Division cooperate in this work with the Sanitary Engineering Section of the American Society of Civil Engineers, the American Public Health Association, and other similar agencies in order that the greatest progress may be made and duplication of effort avoided.

After the business meeting John Gamber, State Fire Marshal, spoke on Fire Prevention.

M. L. ENGER,
Secretary.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Well Water. F. W. G. CLARK. Pekin and Tientsin Times. British Municipal Council's scheme of a deep well system for Tientsin is first of its kind in the Far East. First well bored to depth of 460-feet has produced 300,000 gallons daily. The success of this well has caused the Council to decide to bore five more wells. The program of development calls for three complete stations of a standardized similarity, each with a normal capacity of half million gallons daily. During the summer the maximum water demands have risen above a million gallons a day. The concession's first water supply system established in 1899 consisted of pumping water from the river, a somewhat undesirable source. Previous to this date all water used had to be hand-drawn in buckets at the banks of the river.—*A. W. Blohm.*

Cutting Metals Under Water. L. F. HAGGLUND. Paper presented at International Acetylene Association Convention, November 12, 1926. The method developed for cutting metal under water by means of the use of a jet of oxygen upon metal heated by the electric arc is described. The apparatus which permits the cutting of any metal at any divable depth, consists of a generating unit, switchboard and resistance, a supply of oxygen, oxygen gauge and hose, and double conductor hose through which both oxygen and electricity are carried to the torch.—*A. W. Blohm.*

Protective Coatings. E. M. CONVERSE. Paper at Mid-Continent Section, A. S. M. E., December 9, 1926. Cost of corrosion in oil equipment investment of the country is estimated at many millions of dollars annually, indicating that protective coatings at present in general use are not functioning to a satisfactory degree, or they are not used as extensively as the case demands. Following characteristics desirable for an efficient protective coating: Both chemical and mechanical protection should be provided; material should not be affected by underground or atmospheric conditions; it should penetrate to seat of corrosion; the vehicle should permit functioning of inhibitor; protective coating should remain in form of an elastic non-drying film to give long time protection; it must permit of practical application.—*A. W. Blohm.*

The Utilization of Water Power in the Czechoslovak Republic. JOSEPH WOLF. Ministry of Public Works, 1926. Construction of hydro-electric

stations in the Czechoslovak Republic is closely combined with systematic electrification of the state. Water-power resources which could be of importance for electrification are being developed by the state, the state and province, the province and by companies. Twelve electric stations, supported by the state, put into operation at the time of the birth of the Republic, are producing 23,360 horsepower. Work has been started on 10 other hydro-electric power plants with total capacity of 200,960 horsepower.—*A. W. Blohm.*

Report on the Working of the Corporation Water Analysis Laboratory, Madras. Corporation of Madras, 1924–1925. The filter beds at Madras continue to operate with erratic efficiency. Two batteries of seven filters each with three new ones are unable to turn out the whole quantity of filtered water necessary for the city's consumption, especially during the hot weather. The history of filter beds at Kilpauk is very much the same. A white growth in long trailing filaments is formed in the underdrains, filter chambers and on weirs and with it an odor of sulphuretted hydrogen. A careful study of this growth and of the flora and fauna of the Red Hills Lake formed part of the research work of the laboratory. Experiments on artificial filming of slow-sand filters, chlorination and routine analysis of water were carried on.—*A. W. Blohm.*

Side-Suction Centrifugal Pumps More Efficient for Small Capacity. R. K. Annis. Power, **62**: 12, 451, September 22, 1925. For small capacities, efficiency of side-suction pump exceeds that of double-suction pump of similar design.—*A. G. Nolte.*

Practical Pointers in the Art of Softening Boiler-Feed Water. L. L. Baker. Power, **62**: 13, 479, September 29, 1925. In an elementary way, author discusses the tests used to control softening, the meaning of various terms and methods of making various tests.—*A. G. Nolte.*

Direct-Current Motors Fail to Start—Testing for the Trouble. B. A. Briggs. Power, **62**: 13, 485, September 29, 1925. Testing for open-circuits in the field and armature circuits; for fault in the motor; open-circuit in armature and testing series and shunt coils.—*A. G. Nolte.*

Electric Level and Pressure Gage. Power, **62**: 13, 504, September 29, 1925. A new electrical level and pressure gage developed by the Republic Flow Meter Company of Chicago is illustrated and described. It may be used to give the head- and tail-water levels in reservoirs, levels in water and oil supply tanks of all kinds, soap vats, etc.—*A. G. Nolte.*

Surface-Condenser Operation. P. H. Jeynes. Power, **62**: 14, 514, October 6, 1925. Three factors in surface-condenser performance that present opportunities for effecting economies are: (1) amount of circulating water; (2) period between cleanings; (3) refrigeration or cooling of condensate. Each of these factors is discussed.—*A. G. Nolte.*

Equipment for Crushing Coal. W. W. SAYERS. Power, 64: 8, 284, August 24, 1926. Various types of coal crushers are illustrated and described.—*A. G. Nolte.*

The World's Largest Diesel. Power, 64: 8, 287, August 24, 1926. Brief description of the 15,000-hp Diesel purchased by the City of Hamburg, Germany.—*A. G. Nolte.*

Boiler Feed-Water Purification.—9. Priming and Foaming. S. T. POWELL. Power, 64: 9, 330, August 31, 1926. Priming is the discharge of water from a boiler with the steam, by the bursting of steam bubbles. Foaming is the production of froth on the surface of the water. This condition is less violent than priming. Priming and foaming may occur at the same time. Construction of boiler has marked effect on priming and foaming tendencies of boiler water. Recently, experience and special studies have confirmed the theory that priming and foaming are due, not only to the concentration of sodium, or other, soluble compounds, but to the presence of these substances in relatively high concentrations in addition to suspended matter. It appears that the basic principle of foam formation is related closely to the surface tension of the liquid. Where foaming is experienced treatment of the water should receive careful consideration. Most efficient means of preventing foaming is to reduce suspended solids to lowest economical point by external treatment. Same applies to soluble solids which may be precipitated within the boiler and controlled by blowing down. Much can be done to prevent foaming and especially priming of a boiler by the way in which it is operated. A number of appliances for the removal of moisture from the steam as it passes from the steam drum have been placed on the market. The author describes and illustrates a number of them. The detrimental effects that result from the use of wet steam are great. All water that leaves the boiler through the steam line carries with it solids, either in suspension or solution. Solids entering steam lines, turbines, engines, etc., create a potentially troublesome and dangerous situation. Wet steam, whether caused by priming or foaming action or merely the result of the mechanical removal of the boiler water due to high velocity of steam travel, is a phase of boiler-water control that deserves most careful consideration.—*A. G. Nolte.*

Boiler Feed-Water Purification.—10. Embrittlement, What Causes It? S. T. POWELL. Power, 64: 10, 371, September 7, 1926. Inter-crystalline cracking of boiler steel occurring while boilers are in service is termed embrittlement or "caustic embrittlement." It is distinguished thusly from corrosion cracking or cracks due to stresses. Embrittlement failures are indicated by occurrence of fine cracks in the metal below water line. Two theories have been advanced in order to explain the causes of the trouble. Some investigators claim that primary cause of embrittlement is improper processing of the metal and that the concentration of caustic soda in boiler feed-water is not responsible. Opposed to this view is the theory of caustic embrittlement, advocates of which contend that embrittlement is result of absorption of hydrogen released by decomposition of caustic soda which may take place at high temperatures and

pressures and in the absence of other salts (principally sulphates), or at least when these salts are present only in small amounts. Author summarizes the results of extensive experiments by various scientists on embrittlement of boiler metal and sums up the arguments on both sides.—*A. G. Nolte.*

Boiler Feed-Water Purification.—11. Evaporators, Their Design and Operation. S. T. POWELL. Power, **64**: 11, 406, September 14, 1926. The recent tendency toward high boiler ratings and large-sized boilers and the definite trend in favor of higher steam temperatures and pressures have required much greater purity of feed-water than was formerly deemed necessary. Principle of operation of all evaporators is the same. Evaporators are designated in a number of ways, depending upon certain features of their design or the principle upon which they function. Classified as (1) Submerged Tube Type; (2) Film Type; (3) Flash Type. Classified further according to number of effects as—single effect, double effect, triple effect, etc., classification also made as high-pressure or low-pressure evaporators, also as high-heat-level or low-heat-level evaporators. Author illustrates and describes a number of types of evaporators. Cost of operation of evaporators depends primarily upon source of heat utilized. Choice as to type should be dictated by existing conditions with reference to the particular heat balance of the steam station. Priming and foaming may occur in evaporators. At some stations water is filtered before passing to evaporator.—*A. G. Nolte.*

Boiler Feed-Water Purification.—12. Getting Rid of Dissolved Gases by De-aëration. S. T. POWELL. Power, **64**: 12, 441, September 21, 1926. Certain gases dissolved in water accelerate its corrosive action. Open feed-water heaters partly remove them, but practically complete removal of dissolved gases is essential in order to stop corrosion. A number of appliances for degasification now in practical operation eliminate practically all dissolved gases. Two most important gases which accelerate corrosion are oxygen and carbon dioxide. There are two general types of degasification apparatus, designated as, (A) Mechanical or Physical and (B) Chemical. Chemical deoxygenators operate by removal of the oxygen from the water by oxidizing iron or steel or other substances. In one type of mechanical deaërator the gases are removed by explosive boiling of the water as it flows through the apparatus. Another type is based upon the principle of reboiling or scrubbing the feed-water by means of live steam; the gases in the water are removed by being forced upward with the rising bubbles of steam. The author discusses the efficiency of deaërators and describes the operation of several types.—*A. G. Nolte.*

Boiler Feed-Water Purification.—13. Corrosion, Its Cause and Cure. S. T. POWELL. Power, **64**: 13, 471, September 28, 1926. During last century many theories have been proposed to account for failures due to corrosion, namely, the acid theory, the biological, the film, the peroxide, the direct oxidation, and the electro-chemical theories. The latter has been confirmed by a number of investigators. Author briefly explains this theory and further discusses corrosion due to dissolved oxygen, mineral acid, alkalinity of water, carbonic

acid, and acid produced from salts in feed-water. Summarized briefly, the principal factors influencing steam-boiler corrosion are as follows: (1) The presence of gases in the feed-water particularly dissolved oxygen; (2) The hydrogen-ion concentration (acidity or alkalinity) of the feed-water; (3) The velocity of the water passing over the metal; (4) The temperature and pressure maintained in the boiler. Author concludes with brief discussion of prevention of corrosion in steam boilers.—*A. G. Nolte.*

Storing Bituminous Coal. W. T. CONLON. Power, **64**: 10, 354, September 7, 1926. Loss in heat value from bituminous coal in storage may, in general, be considered as negligible, as it seldom exceeds one per cent of total heat content. There are exceptions, however, and as a rule it is a difficult matter to determine from laboratory analysis. There is at times, a change in steaming qualities of coal due to weathering. The greatest storage loss occurs from spontaneous combustion which is caused by an exothermic absorption of oxygen. In a coal pile with many voids, the oxygen absorbed is automatically replaced, due to air circulation. Filling the voids with coal will by cutting down air circulation and oxygen absorption reduce the likelihood of spontaneous combustion. A suggested method of storing coal is in layers approximating but not exceeding, three feet in depth, by use of drag scrapers or otherwise, keeping in mind that voids should be filled with "fines" and a more or less uniform structure maintained throughout the pile. Rolling and packing give further insurance against fire hazard.—*A. G. Nolte.*

How to Lay Out Power-Plant Piping. S. CROCKER. Power, **64**: 11, 398, September 14, 1926. The design of pipe hangers and anchors is discussed.—*A. G. Nolte.*

Testing a Surface Condenser in Action. C. E. COLBORN. Power, **64**: 12, 431, September 21, 1926.—*A. G. Nolte.*

How to Lay Out Power Plant Piping. S. CROCKER. Power, **64**: 13, 478, September 28, 1926. Heat insulation is considered. The proper thickness and kind of covering for different pipe sizes used under different classes of services is worthy of study. A table of pipe covering standards for various services in the Detroit Edison Company's Plants is given.—*A. G. Nolte.*

Routine Inspection Procedure for Power-Station Equipment. C. R. REID. Power, **64**: 13, 482, September 28, 1926. In large generating stations it is desirable to systematize the work of inspection of the great variety of apparatus. Author gives an excellent résumé of methods of inspection and record keeping in the larger power houses of the Shawinigan Water and Power Company, Shawinigan Falls, Quebec. These methods can be used as a basis for working up a systematized schedule for almost any size or type of plant.—*A. G. Nolte.*

Experimental Studies of Water Purification. (1) Description of Plant. F. J. Moss. Public Health Reports, **41**: 40, 2121, October 1, 1926. A brief

engineering description is given of experimental water purification plant on grounds of stream pollution investigations laboratory at Cincinnati, Ohio. It is of rapid sand type, similar in its main features to most of the full-scale plants on inland streams in the United States. Some features designed especially for experimental purposes are as follows: provision for delivering to plant river water, domestic sewage, clear dilution water, or a combination of any of these; parallel division of the plant into two independently functioning halves; an unusual flexibility in the arrangement and interconnection of the various units. Plant operated usually during 24 hours each day and six days a week. Routine collection of water samples carried out on an extensive scale. (2) **Preliminary Review of Results of Primary Experiments.** H. W. STREETER. Experiments designed to test the maximum degree of raw water bacterial pollution consistent with production of effluents conforming to given standards of bacterial quality. Experimental plant was arranged so as to permit bacterial content and physical character of raw water to be varied over a wide range. Some of the results of observations indicated: (1) that a consistent relationship exists between the bacterial quality of the raw water and that of the effluents produced from it at successive steps of treatment; (2) that this relationship is a simple power function and can be expressed by a general equation; and (3) that results obtained from the experimental plant may be applied, without substantial modification, to full scale municipal plants of the same type and design and treating raw waters of the same quality.—*A. G. Nolte.*

Bitumen Determinations in Coarse Asphaltic Concretes. A. R. EBBERTS. Eng. News-Rec., 97: 513–4, 1926. Method is described for determining whether bitumen content of asphalt concretes conforms to specifications. By dividing the amount of bitumen specified by the total superficial area of the ideal grading as determined by the specifications, a value termed the bitumen index is obtained. Comparison of bitumen content found on extraction with value obtained by multiplying the superficial area of the aggregate after extraction by the bitumen index, determined as above, shows whether the specimen is of the desired composition. A chart is given for determining the superficial area of the aggregate from the sieve analysis.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Illuminating Gas for Metal Cutting. Eng. News-Rec., 97: 54, July 8, 1926. Illuminating gas has replaced acetylene, hydrogen, and other fuel gases in combination with oxygen metal for cutting at Schenectady plant of General Electric Co., a special torch having been developed for the purpose. Illuminating gas has been found to be cheaper than either hydrogen or acetylene, while cutting speed after starting is approximately equal for all gases. Use of illuminating gas permits use of torch equipped with superheater, thus effecting marked economies in oxygen at cutting jet.—*R. E. Thompson.*

Colorado Springs, Colo. Eng. News-Rec., 97: 17–19, July 1, 1926. The combined hydro-electric and water supply system is described. Supply is derived from southern slope of Pike's Peak. Three of watersheds contain

storage reservoirs. Water is delivered from supply lines to 3 distribution reservoirs, from which city is supplied by gravity in two services. Chlorination, by Williams electrolytic method, is employed when necessary. Only 30 per cent of water is metered. Flat rate for 50-foot lot is $15 per year. Meter rate is 15 cents maximum and 8 cents minimum. Maximum consumption is 10 million gallons per day, and per capita consumption 180 gallons per day.—*R. E. Thompson.*

Setting Time of Cement Indicated by a Machine Operation. A. A. JAKKULA. Eng. News-Rec., 97: 66, 1926. An apparatus is described and illustrated which automatically indicates the time of set of cement.—*R. E. Thompson (Courtesy Chem. Abst.).*

Flood Protection for Dallas, Tex. Eng. News-Rec., 97: 58, July 8, 1926. Brief data given on revised project for flood protection and land reclamation along Trinity River at Dallas, Tex.—*R. E. Thompson.*

Snow Surveys and Stream Runoff in the Sierra Nevada. Eng. News-Rec., 97: 7, July 1, 1926. Tabulation is given of comparison of actual runoff of 7 basins in Sierra range with runoff predicted by surveys conducted by the Nevada Co-operative Snow Survey. In report on 16 years' snow surveying, J. E. CHURCH, JR., states that of 54 forecasts made, 29 were within 10 per cent of actual runoff, 14 within 20 per cent, and in remaining 11 maximum divergence was 30.4 per cent.—*R. E. Thompson.*

Well Sinking and Tests for the City of Los Angeles. GEO. R. SHUEY. Eng. News-Rec., 97: 8–9, July 1, 1926. Illustrated desciption of methods employed in sinking and testing wells in Owens Valley which are used in times of drought to supplement gravity supply of Los Angeles.—*R. E. Thompson.*

Large Ditch-Lining Job Done at Low Cost and High Speed. Eng. News-Rec., 97: 52–3, July 8, 1926. Description of 1–1½-inch gunite lining placed in east side main canal on Salt River irrigation project in Arizona. The section completed is 16 miles in length and required 4,500,000 square feet of lining. The remaining 16 miles, requiring 3,500,000 square feet of lining, will be completed at close of present irrigation season. Average of 4700 square feet per gun per 9-hour shift was maintained throughout work. Labor cost averaged 1.15 cents per square foot and total cost, including plant, 9½ cents per square foot.—*R. E. Thompson.*

Cylinders for Concrete Samples Made Up on Job. Eng. News-Rec., 96: 1032–3, June 24, 1926. Brief illustrated description of cylinders used on Balch project of San Joaquin Light and Power Corporation which were made at cost of $4 each. Factory-made cylinders for this purpose cost $20 each.—*R. E. Thompson.*

Advantages Shown for Wire-Willow Mattress Over Basket-Weave Type. F. Y. PARKER. Eng. News-Rec., 96: 1033, June 24, 1926. Brief illustrated

description of type of mattress woven on No. 9 galvanized wire mesh which requires less ballast and ⅓ less willows, than standard basket-weave type. Bar-growth willows one season old can be effectively used, and cost is about $2 less per 100 square feet.—*R. E. Thompson.*

Effect of Sulfur on Rivet Steel—Summary of Findings. Eng. News-Rec., **97**: 26, July 1, 1926. The Joint Committee on Investigation of the Effect of Phosphorus and Sulfur in Steel of the American Society for Testing Materials report that sulfur up to at least 0.06 per cent is not detrimental. Above this amount many of the strength properties are unaffected, but ductility, impact resistance and shearing strength of riveted joints are decreased. Data obtained presented graphically.—*R. E. Thompson.*

Pipe Line Construction for Athens, Greece. J. P. HANLEY. Eng. News-Rec., **97**: 28, July 1, 1926. Brief outline of construction of pipe line feeding Acican and Neurvia reservoirs, Athens.—*R. E. Thompson.*

Tests on Growing Vegetation on Gravel Dams. C. H. EIFFERT. Eng. News-Rec., **97**: 55–58, July 8, 1926. Details given of results of experimental plantings on hydraulic fill dams and levees of Miami Conservancy District in Ohio to determine most suitable grasses for providing protective covering for parts of slopes not protected by riprap or revetment.—*R. E. Thompson.*

Tests Show how Calcium Chloride Affects Concrete. A. S. LEVENS. Eng. News-Rec., **97**: 214–5, 1926. The effect of 2, 3, 4, and 5 per cent of $CaCl_2$ as an integral part of mix on the tensile strength of concrete was determined. The strongest concrete was that which contained 2 per cent $CaCl_2$, higher percentages tending to weaken. During the earlier periods (3–7 days) strength of concrete containing 2 per cent $CaCl_2$ was 40 per cent greater than that of plain concrete. Similarly, strength under compression showed an increase of 106 per cent. Shrinkage was 100 per cent greater than in plain concrete at 3 days, 50 per cent at 7 days, and 85 per cent at 14 days and thereafter.—*R. E. Thompson (Courtesy Chem. Absts.).*

Rust-Preventive Paints from an Electrolytic Standpoint. E. LIEBREICH. Farbe und Lack, 1925, 602. From Chem. Abst., **20**: 995, March 20, 1926. Use of an alkaline salt in priming coat of paint on metal, followed by two coats of durable paint, gives better protection against rust than if alkaline salt is not present to inhibit electrolytic corrosion. Finishing coats prevent water-soluble alkaline salt from being washed out. If ordinary paints were impermeable to water they would effectually prevent rusting. Manner in which moisture penetrates paint films by imbibition is discussed.—*R. E. Thompson.*

Rust-Preventive Materials. JULIUS SWOBODA. Chem.-Ztg., **49**: 977–9, 994–7, 1925. From Chem. Abst., **20**: 995, March 20, 1926. Review of theories of corrosion of iron, of metallic coatings, lacquer, asphaltic preparations, portland cement, heavy mineral oils and greases, metallic soaps, paints, etc., used as rust preventives.—*R. E. Thompson.*

Fighting Rust with Sublimed Blue Lead. The Eagle-Picher Lead Co. Chicago. 82 pp. From Chem. Abst., 20: 964, March 20, 1926. Assemblage of facts concerning properties and uses of sublimed blue lead.—*R. E. Thompson.*

Sectional Concrete Roadway Valve Boxes for Baltimore Water Works. V. BERNARD SIEMS. Eng. News-Rec., 97: 374, September 2, 1926. When concrete vaults were first adopted in Baltimore instead of cast-iron roadway boxes, they were purchased at $2.75 each. Considerable saving has been effected by manufacturing pre-cast sectional vaults at the City yards, 1275 having been made during 1925 at average cost of $1.52 each.—*R. E. Thompson.*

Laying Water Main in Swift Current. THOS. TREMBLAY. Cont. Rec., 40: 207, March 3, 1926. Brief illustrated description of laying of 16-inch main across St. François River at Sherbrooke, Que. River is 350 feet wide, about 8 feet deep, and has a very swift current. Pipe was installed when river was covered with ice, being lowered into position from wooden trestles erected prior to freezing of river. Work was completed in 7 days by 14 men.—*R. E. Thompson.*

Silicate Protective Coatings for Artificial Stone. F. HUTH. Farbe und Lack, 1925, 606. From Chem. Abst., 20: 977, March 20, 1926. Review of use of sodium silicate for hardening concrete floors, artificial building stone, etc.—*R. E. Thompson.*

Concrete Strength Made Uniform by Careful Proportioning. ZARA WITKIN. Eng. News-Rec., 97: 258–9, 1926. Data given on quality of concrete produced during construction of a building on which 3 field methods were employed, (1) volumetric measurement of aggregates, (2) weight measurement of fine aggregate, and (3) inundation of fine aggregate. Following conclusions are drawn from observations made: (1) Accurate control of water content of aggregates, using same theoretical mix, effected reduction of 6–7 per cent in amount of cement required. (2) With accurate water content control and constant mix, strength is an inverse function of slump. (3) With accurate water content control, strength with same theoretical mix is slightly higher and considerably more uniform.—*R. E. Thompson (Courtesy Chem. Abst.).*

Experiments on Accelerated Testing of Rust-Preventive Paints. HANS WOLFF. Korrosion und Metallschutz, 1925, 85: 130; Farben-Ztg., 31: 706; cf. C. A., 19: 2418. From Chem. Abst., 20: 995, March 20, 1926. For accelerated testing, painted panels are placed in glass cylinder through which air of various relative humidities and temperatures, or containing various amounts of corrosive gases, is circulated. Results are compared with those obtained on outside exposure. Exposure of film shortly after drying to strong sunlight is conducive to cracking. High humidity has less effect on drying of white lead paint than on that of zinc oxide paint.—*R. E. Thompson.*

Influence of Sugar on the Properties of Cement. Sucr. belge, 44: 612, 1925. From Chem. Abst., 20: 976, March 20, 1926. Resistance to compression of

cement blocks that were made with water containing 0.1 per cent sugar is superior to that of blocks made from cement mixed with pure water. It was also found that wet concrete coming in contact with sugar is stronger than concrete that is merely wet with water.—*R. E. Thompson.*

Procedure for Analysis of Mortars. JAMES L. HEITZMAN. Eng. News-Rec., **97**: 271, 1926. Method is described for determining approximate composition of mortars. Weigh out 1 g. of crushed and dried sample, add 50 cc. dilute HCl (1:9) and boil until all soluble material is in solution. Filter, ignite, and weigh. This weight $\times \frac{100}{95}$ = sand content. Evaporate filtrate to dryness cool, add 20 cc. dilute HCl (1:1), warm until Fe salts are in solution and then add 50 cc. distilled water. After boiling, filter, ignite and weigh. This weight $\times$ 500 = approximate percentage of portland cement. Dirty sand would introduce an error in this calculation. Determine CaO and MgO in filtrate in usual manner. Calculate the CaO and MgO in the cement by multiplying latter by 0.625 and 0.032 respectively, and subtract these amounts from the total CaO and MgO found. The combined remaining CaO and MgO $\times \frac{100}{95}$ = approximate percentage of lime.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

An Exposure Test of Water-Line Paints. E. F. FIGG. J. Oil Colour Chemists' Assoc., **8**: 314–34, 1925. From Chem. Absts., **20**: 994, March 20, 1926. Priming coat of red lead in raw linseed oil with finishing coat of white lead in linseed oil tinted with lampblack and two coats of zinc oxide and zinc dust in raw linseed oil gave good protection. Rust inhibition expected from basic lead chromate in raw linseed oil was not confirmed; better protection was obtained with iron oxide-raw oil paints. Use of varnish, in general, decreased durability. Bituminous paints did not show up well. Only one of six commercial paints specially intended for water-line protection gave satisfactory results; this consisted of zinc oxide in slightly thickened linseed oil.—*R. E. Thompson.*

Preparation of Metal Surfaces for Painting and Lacquering. W. J. MISKELLA. Paint, Oil and Chem. Rev., **80**: 27, 10–11, 1925. From Chem. Abst., **20**: 995, March 20, 1926. Importance of thorough cleaning of surfaces to be painted especially of those to be lacquered is emphasized. Removal of slushing compounds and general cleaning of sheet metal discussed.—*R. E. Thompson.*

Partial Evaporation of Trade Waste Eliminates Taste in Water. R. L. MCNAMEE. Eng. News-Rec., **96**: 95–6, 1926. Creosote taste in water supply of Escanaba, Mich., drawn from Little Bay de Noc, was traced, by sampling through the ice, to chemical works discharging considerable volume of wood distillation waste. An arbitrary measure of intensity of taste-producing constituents, termed the taste-index, was employed, being the number of thousand parts of water to which 1 part of sample will impart perceptible taste. Waste from a Myers still, which had a taste index of 300, was found to be

responsible for 96 per cent of the taste although its volume was only 1 per cent of total waste of plant. Evaporation of 10 per cent of this waste eliminated 96 per cent of the taste-producing substances. Thus by evaporating 0.1 per cent of total waste of plant, 92 per cent of taste-producing constituents were removed.—*R. E. Thompson (Courtesy Chem. Abst.).*

The Softening of Boiler Waters. P. WIEGLEB. Chem.-Ztg., **49**: 835, 856–7, 1925. From Chem. Abst., **20**: 957, March 20, 1926. Two methods of water softening are described: (1) treatment with lime and soda, or by permutit system, and (2) mechanical method consisting of preliminary removal of suspended matter followed by evaporation and condensation of boiler water by means of series of evaporators, heat exchangers, and condensers.—*R. E. Thompson.*

Micro-Determination of the Oxygen Content of Water. C. RISCH. Biochem. Z., **161**: 465–7, 1925. From Chem. Abst., **20**: 957, March 20, 1926. Sample of water in collector of known volume is treated without exposure to air, with potassium iodide, sodium hydroxide and manganous chloride. Container is closed and shaken for 1 hour in dark and iodine formed titrated with sodium thiosulfate.—*R. E. Thompson.*

Purification of Dairy Wastes. F. DIENERT. Lait, **5**: 873–81, 1925. From Chem. Abst., **20**: 959. March 20, 1926. Chemical purification, spreading on soil, bacteriological decomposition, and activated sludge process discussed.—*R. E. Thompson.*

Salt Content of Colorado River Increased in 25 Years. CARL S. SCOFIELD. Eng. News-Rec., **96**: 131–2, 1926. Results of analyses of Colorado River water for 3 yearly periods from October 1, 1922, to September 30, 1925, are given, together with results of similar studies carried out in 1900 and 1905. Salt content ranged from 210 to 1250 p.p.m., means for the 3 years being 896, 839, and 997 respectively, compared with 713 and 723 in 1900 and 1905 respectively. The constituents, expressed as reacting values, during the last year reported were Ca 5.82, Mg. 2.56, HCO_3 3.64, Cl 3.62, SO_4 7.82. The average hardness for the 3-year period was 260 p.p.m. as $CaCO_3$, the percentage hardness, i.e., the proportion of alk.-earth bases to the total reaction units, being 56, 53 and 55 per cent for the 3 years respectively.—*R. E. Thompson (Courtesy Chem. Absts.).*

Gravel Wall Well at Leamington, Ont. Contract Rec., **40**: 200–1, March 3, 1926. Principle of gravel wall well is discussed and installation in Leamington, Ont., described briefly. The 3 existing 10-inch wells, 50 feet deep, became inadequate and an 18-inch gravel wall well was installed by Layne & Bowler Company, under contract to supply 400 Imperial gallons per minute. Production of completed well was 438 gallons per minute, compared with combined production of 539 by existing wells, and was only 3 gallons less 1 year later. Power consumption by the direct driven vertical centrifugal pumps is 0.3 kw. hours per 1000 gallons, and cost of delivery of water into reservoir is 0.9 cents.—*R. E. Thompson.*

Methods of Testing the Thickness of Zinc Coatings. HEINZ BABLIK. Metal Ind. (London), **28**: 33–5, 1926; cf. C. A., **19**: 2629. From Chem. Abst., **20**: 896, March 20, 1926. Experimental results show that increase in weight after zinc-coating is no measure of amount of coating. Author believes reagents proposed by Bauer (concentrated sulfuric acid 20 grams, water 500 cc., and arsenious oxide 2 grams) and by Aupperle (concentrated hydrochloric acid 100 cc. and 5 cc. of solution prepared by dissolving 20 grams of antimony oxide in 1000 cc. concentrated hydrochloric acid) are best. Defects in gas-evolution and temperature-increase methods are pointed out.—*R. E. Thompson.*

ABSTRACTS, SUBCOMMITTEE NO. 9

JOINT RESEARCH COMMITTEE ON BOILER FEEDWATER STUDIES

Utilization of Condensing Water for Boiler-Feed Purposes (Die Frage der Kondenswasserverwertung für Kesselspeisezwecke). A. STERN. Wärme, **49**: 50, December 10, 1926, pp. 868–870, 1 fig. Advantages and disadvantages of lime in feedwater; boiler corrosion due to air in feedwater; enrichment of air in feedwater by use of feed pumps; automatic boiler-feed plants which prevent absorption of air; how high-pressure boilers should be fed.

Boiler Disencrustants. A. SETON. Eng. & Boiler House Rev., **40**: 7, January 1927, pp. 364–365. Deals with softening of water in boiler whereby formation of scale is prevented to some extent, and discusses disencrustants of different makes.

Complete Removal of Oil from Feedwater (Hot volkomen olie-vrij maken van het voedingwater). J. C. DIJXHOORN. Het Schip, **8**: 23, November 12, 1926, pp. 332–333, 1 fig. Application of Dijxhoorn system of oil separators; as example 1 kg. sodium salt and 3 kg. alum are used to treat 24 tons feedwater.

Feed Water Preparation. Power Plant Eng., **31**: 2, January 15, 1927, pp. 119–129, 14 figs. Feedwater heater; water and steam purification; present status of economizer practice.

Principles of Modern Specifications for Boiler Feed-Water (Neuzeitliche Beurteilungsgrundsätze für Kesselspeisewasser). A. SPLITTGERBER. Zeit. für angewandte Chemie, **39**: 44, November 4, 1926, pp. 1340–1345. Necessity of careful analytical control of boiler feedwater, before and after softening, for efficient and economical running, is emphasized, and methods of softening are described.

Feed Water Treatment in Power Plants. Power Plant Eng., **31**: 1, January 1, 1927, pp. 25–28, 2 figs. Higher steam pressures and demand for higher ratings have made feedwater treatment problem of vital importance.

Railroad Water Treatment. West. Soc. Engrs. Jl., **31**: 10, October, 1926, pp. 392–402 and (discussion) 402–407. Contains three papers giving general view of water-treating practice on American railroads, as follows: **History**

and Growth of Water Treatment for Locomotive Boilers, R. E. COUGHLAN; **General Aspects of Water Treatment for Railroads,** R. C. BARDWELL; **Zeolite Method of Water Softening,** C. STURDEVANT.

Recent Developments in Feed-Water Treatment. E. H. TENNEY. Power Plant Eng., 31: 1, January 1, 1927, pp. 23–24, 2 figs. Practice in chemical methods of treatment, evaporation deaëration, and stage feedwater heating.

Recent Influences on Boiler Water Treatment. J. D. YODER. Power Eng., 30: 24, December 15, 1926, pp. 1316–1318, 2 figs. Of many recent innovations in power plant design, those closest related to boiler-feedwater treatment have been higher ratings and higher pressures at which it has been found economical to operate boilers; hot-process water softener; use of trisodium phosphate; maintaining proper sulphate-carbonate ratios.

The Scientific Treatment of Boiler Feed Water, Introducing the Colloidal Aspect. W. B. LEWIS and S. G. IRVING. Ceramic Soc.—Trans., 25: 1925–26, pp. 200–205 and (discussion) 205–208. Application of colloidal chemistry to feedwater problems; water-softening plants; oxygen and corrosion.

The Origin and Prevention of Corrosion in Boilers (Die Entstehung und die Verhütung von Korrosionen in Dampfkesseln). P. WIEGLEB. Brennstoff u. Wärmewirtschaft, 8: 22, December 1, 1926, pp. 369–373, 2 figs. Discusses four causes of corrosion by feedwater, namely: gases dissolved in water, insoluble and soluble materials, and volatile acids.

Boiler Protection and Maintenance. Mar. Engr. & Motorship Bldr., 49: 592, December, 1926, pp. 466–467, 1 fig. Particulars of filtrator, a simple device which prevents formation of boiler scale.

Boiler-Scale and Rust Prevention in Hot Water (Die Verhütung von Kesselstein und Rost in heissem Wasser). M. GROECK. Gesundheits-Ingenieur, 49: 48, November 27, 1926, pp. 740–742, 1 fig. Describes Riwog water-transformation process, according to which lime and corrosion problem is solved.

Cleaning Condenser Tubes. Power, 65: 2, January 11, 1927, p. 64. Laboratory experiments by Elliot Co. indicate that proper acid concentration to use in removing condenser-tube scale is 2.5 per cent solution by volume of hydrochloric acid for treatment of one hour's duration.

Scale Prevention on Fire Tube Boilers. Universal Engr., 44: 6, December 1926, pp. 25–26, 1 fig. Survey of heavy scale formation in boilers of Monmouth Memorial Hospital, Long Branch, N. J., resulting in installation in 1923 of De-Concentrator supplied by Hagan Corp.; De-Concentrator has entirely prevented formation of scale, sediment remaining in boiler being soft and readily washed out, and small in amount as compared with former quantity of scale.

Feeding Locomotive Boilers (Ueber die Speisung des Lokomotivkessels). D. R. P. WAGNER. Verkehrstechnik, no. 47, November 19, 1926, pp. 801–805, 6 figs. Discusses development of feedwater heaters; flue gas heaters; preheaters; steam jet pumps; exhaust preheaters; quantity of heat consumed and delivered by various types.

Direct Titrometric Methods for Magnesium, Calcium, and Sulphate Ions and Their Application in Water Analysis. E. P. SCHOCH. Indus. & Eng. Chem., 19: 1, January, 1927, pp. 112–115. Titration of magnesium, calcium, and sulphate; determination of permanent hardness or of sodium carbonates in natural waters; determination of amounts of lime and soda required to soften water.

Water Softening Problems and Their Remedies. F. S. TAYLOR. Water Works Eng., 79: 24, December 15, 1926, pp. 1579–1580 and 1607–1608, 5 figs. Some troubles experienced in new electric plant; how these were met and overcome and excellent results obtained.

Effect of Hydrogen-Ion Concentration in Revivifying Zeolites. O. R. SWEENEY and R. RILEY. Indus. & Eng. Chem., 18: 12, December, 1926, pp. 1214–1216, 5 figs. It is shown that pH value of water softened should be important control constant for all waters for use in commercial softeners.

NEW BOOKS

Druckrohrleitungen: Berechnungs- und Konstruktions- Grundlagen der Rohrleitungen fur Wasserkraft- und Wasserversorgungsanlagen. FELIX BUNDSCHU and ADOLF LUDIN. Berlin: Julius Springer. Paper; 6 × 9 inches; pp. 60; illustrated. 6 reichmarks in Germany. Reviewed in Eng. News-Rec., 97: 674, October 21, 1926.—*R. E. Thompson.*

Von der Bewegung des Wassers, und den dabei Auftretenden Kräften: Grundlagen zu einer praktischen Hydrodynamik für Bauingenieure. ALEXANDER KOCH and MAX CARSTANJEN. Berlin: Julius Springer. Cloth; 8 × 10 inches; pp. 228; 331 halftones and line cuts; 2 folding plates. 28.5 reichmarks in Germany. Reviewed in Eng. News-Rec., 97: 675, October 21, 1926.—*R. E. Thompson.*

Theory of Water Hammer. LORENZO ALLIEVI. Translated by EUGENE E. HALMOS. Printed in Rome, Italy. Paper; 7 × 11 inches; two volumes, 119 pp. of text in one, 44 plates in other. Copies may be had free of charge from either American Society of Civil Engineers or American Society of Mechanical Engineers, 33 W. 39th, St., New York City. Reviewed in Eng. News-Rec., 97: 675, October 21, 1926.—*R. E. Thompson.*

Descriptive Bibliography on Oil and Fluid Flow and Heat Transfer in Pipes. Technical Series Bulletin, Missouri School of Mines, Rolla, Mo. JOE B. BUTLER. This bulletin of 62 pages lists and describes 370 references to published

articles and books. The references are arranged chronologically as to year of publication, are fully cross-referenced, and are indexed as to subject, author, and periodical. A short article on the flow of oil in pipes gives formulas, data and procedure in solving problems.

All articles with data on friction loss and heat transfer in oil flow are included. Of the articles on flow and heat transfer in pipes of water, air, steam, and gases, only those with data pertaining to fluids in general are listed. Articles on critical velocity, viscosity and viscosimetry are included if they have applications to oil or fluid flow in pipes.

In 1914, Stanton and Pannell experimentally established for fluid flow in pipes that the friction factor in the ordinary hydraulic formulas is a function of the ratio of the inside diameter of the pipe times the average velocity of flow times the specific gravity of the fluid divided by the absolute viscosity of the fluid. Curves showing this relation over both the streamline and turbulent régimes of flow are plotted from experimental data on water, air, oil and steam. The author lists 51 references having data or curves applicable to oil over both régimes of flow.

Copies of this bulletin may be obtained by writing to the Librarian of the Missouri School of Mines, or to the author.